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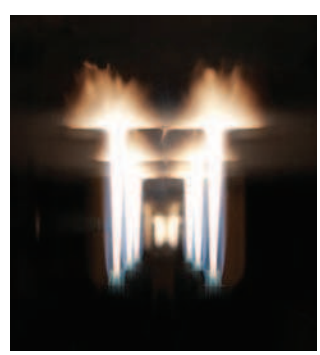

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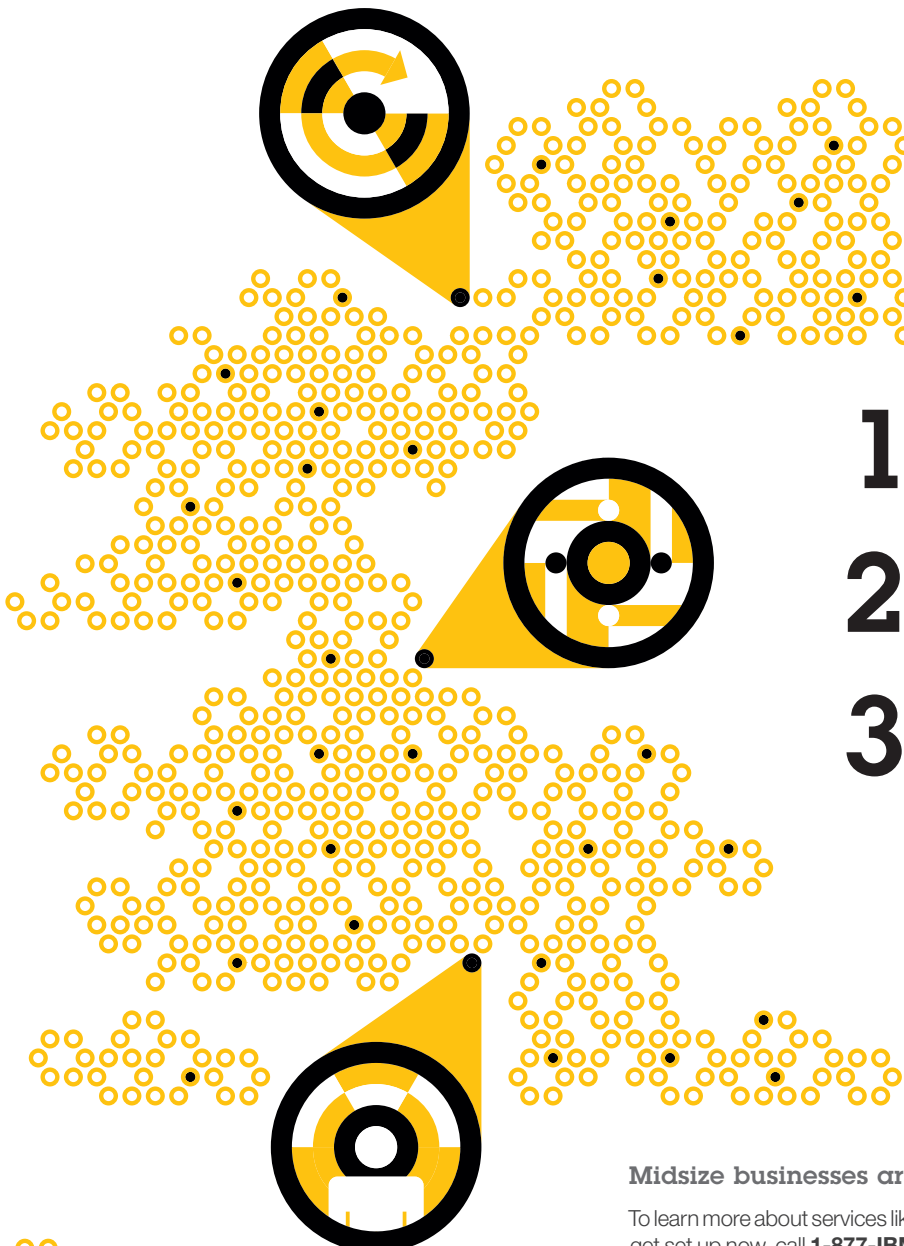

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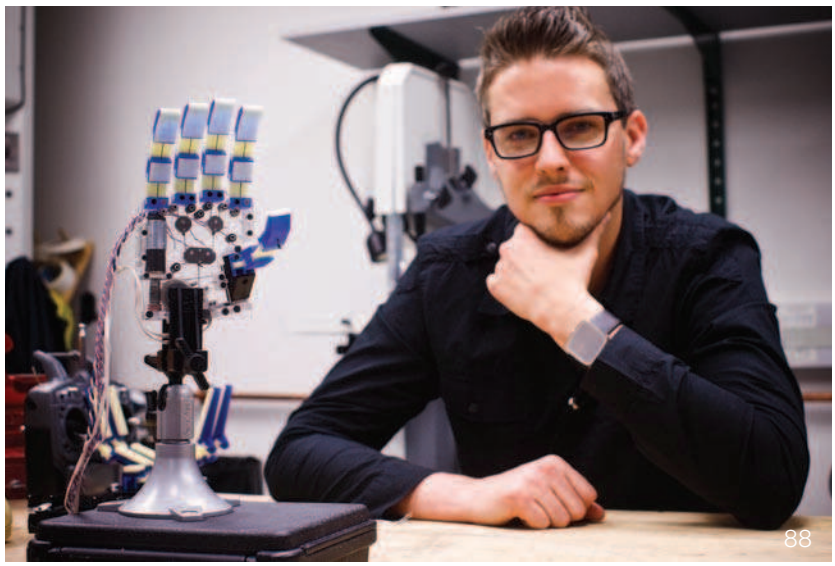

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WHY 35?

Each year that *Technology Review* releases the TR35 (September/October 2010), I find myself reacting very negatively to the criterion that the inventors be under the age of 35. Perhaps it is because my age is now the transposition of these digits, but to me there is something offensive about putting so much value in featuring young innovators. I would prefer that you just list the top innovators of the year regardless of their ages.

September/October '10

Jonathan Simon
Pleasant Valley, Connecticut

The editor in chief responds: When we select 35 innovators under 35, we don't mean to imply that 65-year-olds aren't capable of innovation. Of course they are. We search for innovators under 35 because stories about them and their work will be new to our readers.

GATES AND ENERGY

As a senior fellow at the Tellus Institute, I thought some of the points raised by Bill Gates in your September/October 2010 Q&A were problematic. I agree with Gates that getting the United States to zero carbon emissions will be very hard, but I was disappointed in the stress that he put on funding research and development in new technologies in order to develop energy "miracles." The physics and engineering of most energy technologies have been fairly well known for 50 to 150 years, so we know that miracles or major new breakthroughs are not likely to occur. And we know that the efficiencies of both new energy supplies and end-use technologies will improve only very slowly from this point forward. Furthermore, new zero-carbon-emitting energy technologies are not ever likely to cost less than current coal-fired electricity, which Gates thinks is possible and necessary for their success. We need energy policies that mandate the installation of the most efficient end-use technologies we have today, and we need a national investment plan to eliminate almost all fossil fuels from the energy supply over the next 40 years. These investments might easily total $500 billion to $1 trillion per year, but they would create millions of jobs. By ignoring the need to invest hundreds of billions of dollars per year immediately, and by primarily stressing R&D, Gates is doing a disservice to our country.

Richard A. Rosen
Brookline, Massachusetts

WWW The best way to stem the tide of global climate change is with a revenue-neutral carbon tax. If the American electorate were properly educated about a carbon tax—the solution the world's leading economists and scientists agree is best—they would support it wholeheartedly. And it's long past time that we demand that the people who represent us in Washington put good public policy ahead of political expediency.

ClimateTF, 8/25/2010

THE BUSINESS OF PORN

The porn industry is struggling to make money online ("Down the Tubes," September/October 2010) because it takes talent and hard work to achieve anything meaningful in most activities, but porn has no such barriers. Anyone who is willing can have sex on a tape and upload it to the Web, resulting in an oversupply of porn, with diminishing returns. The huge irony is that the porn industry did this to itself. In the old days, porn was difficult to produce due to restrictive moral standards. The limited supply made for good business and fat profits, but nowadays porn is ubiquitous and taken for granted.

gabrielg01
(Gabriel Gaidos, Hanover, New Hampshire)

VALUE OF ANONYMITY

Sites like 4chan ("Radical Opacity," September/October 2010) allow people to be their worst selves without the need to face the consequences of their words and actions. Posting to an online forum is not necessarily harmless. Those who seek to do harm should not be allowed the anonymity to get away with it.

nhabrams06, 8/23/2010

"A place to be wrong" is important—I think you need to understand that. I have used 4chan for bouncing around ideas that I never could anywhere else. I've shared things with people I never would consider. It's therapeutic, and only a small number of anonymous users lash out.

anubite
(Karl Schneider, Cleveland, Ohio)

ENERGY STIMULUS

I think that the U.S. government should get out of the stimulus business and into the regulation business ("Cash for Infrastructure," September/October 2010). I don't trust any government to make the best decision on which energy technologies to develop. I think that the government should figure out what is the cost to pollute (health-care costs for asthma, costs of sea-level rises, costs of acid rain, etc.), and then should tax the pollution source based on the amount of pollution emitted. If the company wants to avoid the tax then it will invest in technology that emits less pollution.

Devere, 8/31/2010

Correction: The algorithm created by TR35 winner Philip Low (September/October 2010) can classify sleep stages using data from a single EEG lead (not LED).

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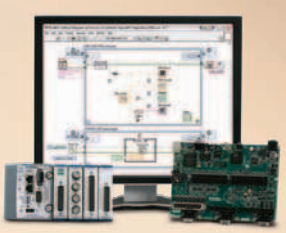

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WEB SERVICES

Online Evolution

Starting an Internet company with the potential to reshape how we use the Web has never been cheaper, says David Cowan.

In 2004 a cabal of programmers in the World Wide Web Consortium (W3C) grew frustrated by the slow pace of innovation in Web standards. They splintered off from the standards body to forge specifications for making Web pages interactive without proprietary browser plug-ins. Three busy years later, their leaders—Ian Hickson of Google and Dave Hyatt of Apple—prevailed on the W3C to recognize their work as the fifth official version of HyperText Markup Language (HTML5).

Updating an arcane technical standard doesn't ordinarily disrupt global industry. But in this case users, Web developers, and investors are eagerly anticipating websites with true drag-and-drop interfaces, video and audio playback, document editing, game play, and more.

The applications that follow such a leap in Web functionality will shape the future of television, music, commerce, business collaboration, gaming, and who knows what else *(see "The Web Is Reborn," p. 46)*. As HTML5 elements are woven into the fabric of the Web, expect creative developers to stitch them together in ways that wreak havoc on the market share of existing companies. HTML5 will make it easier and cheaper than ever for entrepreneurs to commercialize innovative Web services and make them accessible from every computer, phone, and television.

The expected economic windfall reflects a broader trend that my colleagues and I have brazenly dubbed Bessemer's Law. In 1995—at the dawn of the commercial Web—it cost about $20 million to develop, test, secure, and scale an e-commerce application. The time and money required to launch a scalable, secure commercial Web service has since dropped by half every two years, thanks to new technologies like Java, Apache, Adobe Flash, AJAX, XML, Amazon cloud servers, and soon HTML5. Today, $150,000 is a sufficient engineering budget to launch an online startup. This opens the door for entrepreneurs, but it challenges them later, when they need to attract people, capital, and customers in a market crowded with startups.

Bessemer's Law also challenges established venture capital firms like ours. Tempted by the favorable economics of bulkier funds, VCs have been writing larger checks to later-stage companies. But cheaper online startups promise the highest returns to seed-stage investors—the so-called Super Angels. They fund the $100,000 needed to develop an HTML5 Web service that, if successful, will raise its next round from a large VC firm at a 1,000 percent premium. Consequently, we have constrained the size of our venture fund so we can continue to focus time and capital on seed-stage startups.

It will take another year or two to negotiate the details of the HTML5 standard. Meanwhile, engineers at Adobe, Microsoft, MIT's Media Lab, and elsewhere are already rendering it obsolete through their work on multitouch interfaces, location awareness, reality augmentation, and other new Web technologies. As Bessemer's Law marches toward another decade, it's hard to fathom the cascading impact on our businesses and our lives.

DAVID COWAN OF BESSEMER VENTURE PARTNERS HAS INVESTED IN CONSUMER INTERNET STARTUPS BLUE NILE, HOTJOBS, LINKEDIN, PLAYDOM, AND ZOOSK.

ENERGY

Shrinking Nuclear

Compact nuclear power plants may be a lifeline for a struggling industry, writes Jasmina Vujic.

Nuclear power can play a significant role in meeting the world's environmental and energy challenges if sustainability issues are resolved. China, for example, is constructing more than 20 reactors and plans further growth. There and in other countries, the nuclear industry is being revitalized, along with regulatory development and research on the long-term sustainability of the nuclear fuel cycle.

In the United States, however, the field has been sorely neglected for more than 30 years *(see "Giant Holes in the Ground," p. 60)*. Construction of new nuclear power plants has ground to a halt, while support for research and for training the next generation of nuclear engineers has suffered.

In recent years, the Obama administration has effectively eliminated the Yucca Mountain repository for spent nuclear fuel, which had been approved by the previous administration. But on the positive side, it has awarded $8.3 billion in loan guarantees for constructing nuclear plants and formed a blue-ribbon commission to find new ways of dealing with spent waste.

NICK REDDYHOFF

Perhaps most important, it has moved to support the development of small modular reactors that generate less than 300 megawatts, around a quarter the output of U.S. plants under construction today. Those reactors could address some of the nuclear industry's biggest challenges: waste, safety, security and nonproliferation, and the capital cost of construction.

Small modular reactors require less initial capital investment than conventional ones and can have simpler, safer designs. Their modules can be built in factories (unlike the components of a traditional plant, which must be built on site) and can be deployed rapidly. Designs being developed at Berkeley eliminate the need for pumps and pipes. They could run for 20 years on their initial fuel, thus generating minimal waste.

Two U.S. firms, NuScale and Babcock & Wilcox, have already submitted designs to the Nuclear Regulatory Commission. That's attracted venture capital and opened new financing opportunities that would have been unimaginable 10 years ago. A recent meeting on small modular reactors at Berkeley saw the presentation of designs from the United States, Korea, Japan, France, and Russia.

Those designs are still being refined and are not close to being built. Eventually, however, these reactors could be small enough to be transportable, and they could be installed in isolated locations unsuited to traditional plants or dedicated to specific tasks like water desalination, district heating, or hydrogen production. They have the potential to change the face of nuclear energy.

JASMINA VUJIC IS A PROFESSOR AT THE UNIVERSITY OF CALIFORNIA, BERKELEY, AND CODIRECTOR OF THE BERKELEY NUCLEAR RESEARCH CENTER.

NET NEUTRALITY

Fair Connections

Outcry over the Google-Verizon "pact" on wireless broadband overshadows valid debate, says Michael Powell.

The net neutrality debate has the feel of a religious war: the reactions to Google and Verizon's proposal to exempt wireless connections from laws requiring carriers to relay all data with equal priority were just a few decibels lower than the reaction to building an Islamic center near Ground Zero. Amid such evangelical furor, it is tough to find pragmatic solutions that reflect the legitimate points on each side. This is why we have a Federal Communications Commission to handle complex questions like this one instead of putting them to a public referendum.

Both sides can see that wireless networks will take a starring role in the Internet's future *(see Briefing, p. 67)*. So it is crucial to get the policy balance right.

For the wireless carriers, the first concern is network congestion. Spectrum is a limited resource, and networks must rely on the government to make more of it available. But that means taking some from broadcasters and government users—a long, difficult process.

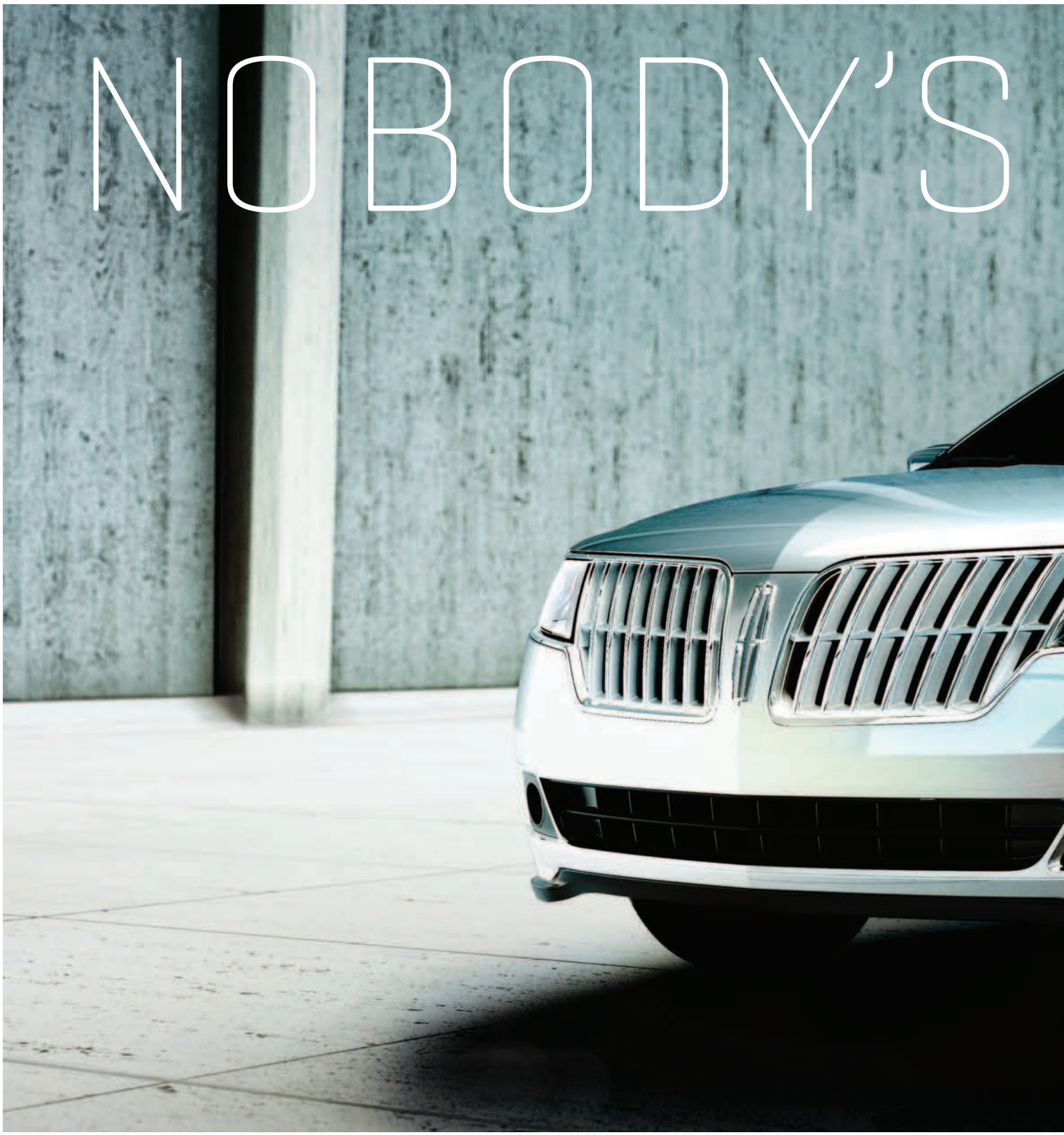
Meanwhile, demand has reached staggering levels with the advent of open networks and app stores. Carriers are finding it more complicated to manage their networks, and they risk alienating customers through dropped calls and ineffective applications. Verizon, which markets its service on the quality of its network, is understandably hesitant to see regulation that limits its flexibility to manage traffic.

The industry's second concern is economics. Analysts predict that there will be more mobile Internet users than desktop users within five years, which might look like a boon for carriers. But data minutes yield much lower revenue than voice minutes do, creating a revenue shortfall as voice use declines. Wireless businesses are concerned that net neutrality rules may prematurely bar the new business models needed to address that shift.

Proponents of wireless net neutrality have legitimate concerns as well. If wireless networks become the central Internet platform, exempting them from the rules could make protections for wired broadband less meaningful. Entrepreneurs working on new wireless applications worry about maintaining access to consumers. Broadband providers without wireless businesses worry about having to follow rules that competitors with such services can dodge.

The truth is that wireless does have unique challenges, but regulations can be written so as to accommodate them. Legitimate technical concerns, not screaming zealots, must guide the FCC.

MICHAEL POWELL IS COCHAIRMAN OF BROADBAND FOR AMERICA AND WAS CHAIRMAN OF THE FCC FROM 2001 TO 2005.



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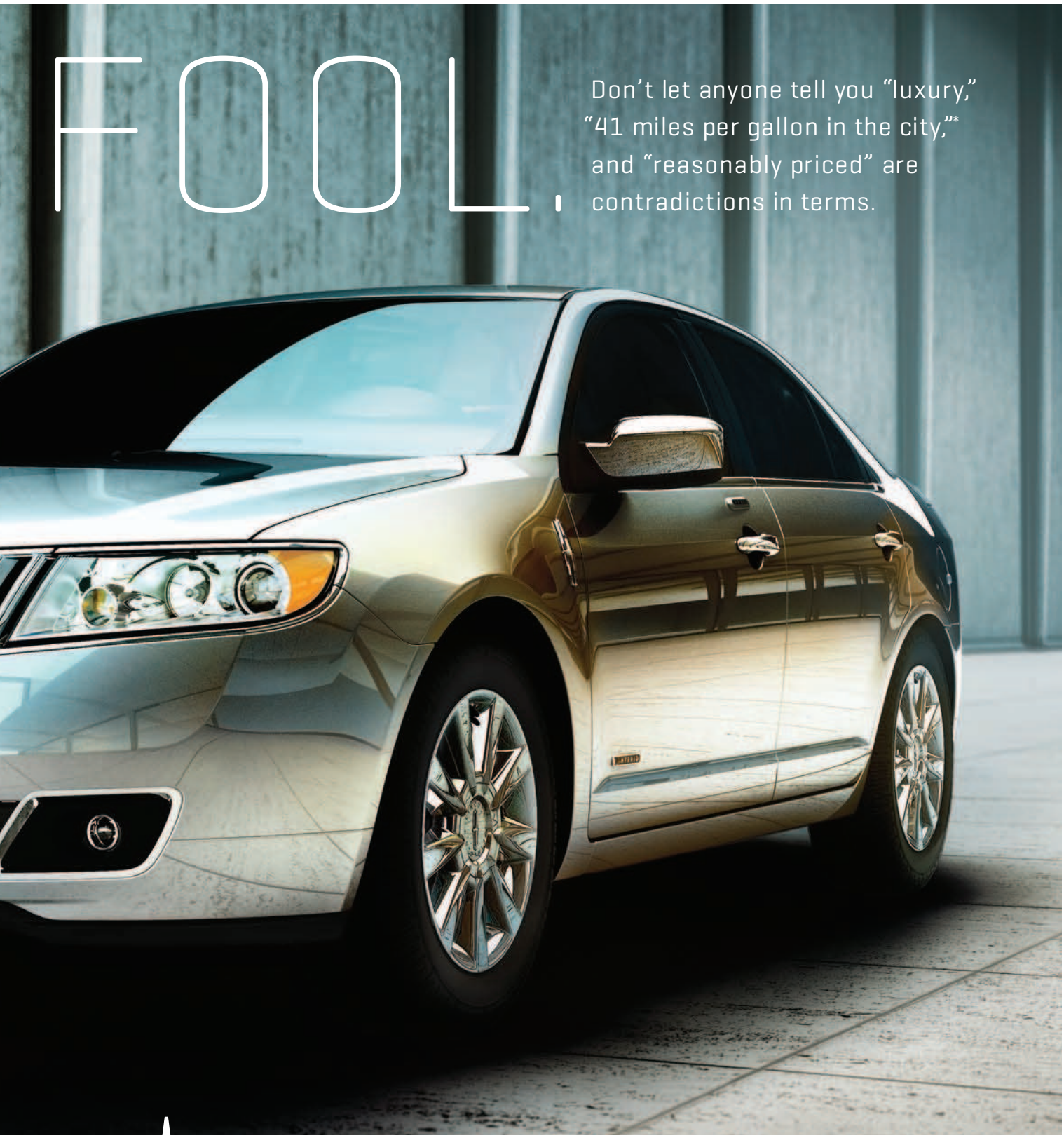

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The Meaning of Our New Designs

Technology Review looks prettier—but new looks express a new strategy.

If you are a subscriber to *Technology Review*, reading this column in a printed or digital issue, perhaps you've noticed that the magazine looks a little different. If you're a regular visitor to TechnologyReview.com reading these words there, you know that the website looks *very* different. And if you're reading this on a tablet like the Apple iPad or a smart phone like a Google Android device, welcome—you are, in the jargon of the consumer technology business, an "early adopter" of one of our new publishing platforms.

Editors place great emphasis on the design of their publications, and the columns they write about redesigns are among the most boring and self-indulgent forms of journalism. Suffice it to say, we'll be happy if you find our magazine and website prettier and easier to use, and if you like to read us on mobile machines. We had good advice. We hired Roger Black, probably the world's most famous publication designer (he has been responsible for the look of magazines as various as *Rolling Stone*, the *New York Times Magazine*, *Newsweek*, the *New Republic*, *Fast Company*, *Reader's Digest*, *Foreign Affairs*, and *Esquire*, and also of websites such as Bloomberg.com and the *Houston Chronicle*'s Chron.com). I think we succeeded in our goals. But write and tell me what you like and what you think doesn't work at jason.pontin@technologyreview.com. If you don't tell me, I'll never know. I promise to write back.

It's more interesting to think about our redesign as a form of institutional psychotherapy: it provided us with the opportunity to reëxamine how we publish our journalism. The new designs are the formalization of a strategy I announced in a column (and elaborated upon in a blog posting), "How to Save Media," in May 2009. Part of that strategy was to expand our number of publishing platforms to include tablets and smart phones. If you've not tried reading *Technology Review* on one of these electronic devices, do: I am sure you'll like it.

We wanted to publish the different kinds of journalism we create on as many platforms as made economic sense, but it was even more important that we should follow a consistent pricing strategy across all those platforms. Last May I wrote: "Content that *some* readers pay for in one medium (now, usually print) should never be offered without charge to *other* readers in another medium (usually electronic). Instead, publishers should distribute editorial to their subscribers on a variety of platforms. This is not to say that much content should not be freely available to readers and paid for by advertising revenues."

For *Technology Review*, this means that starting with this November/December issue, readers must pay to read magazine stories.

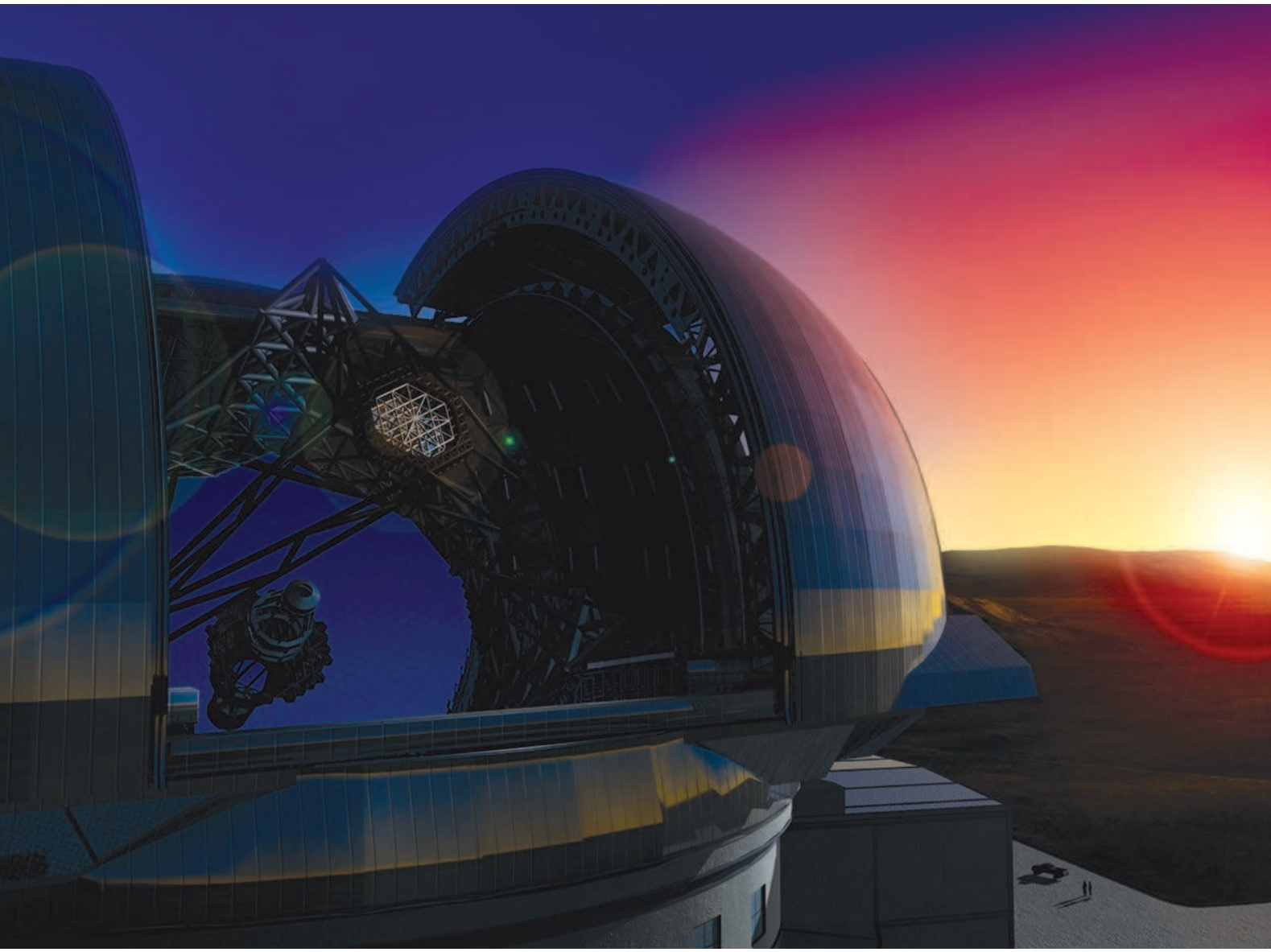
You can purchase a subscription to the print or digital magazine: the latter you can read either in a Web browser or on a tablet or smart phone. All subscribers have access to current and archived magazine stories on the Web. Readers who do not care to pay for a subscription can purchase individual magazine stories or packages of stories on all our electronic platforms. On the Web, readers who don't know if they *want* to subscribe will be given three free magazine stories: a kind of metered journalism. All news stories and blog posts can be read free on all our electronic platforms.

There are other changes for *Technology Review*. This fall we've launched a new online publication, called *Business Impact*. Its editor, Evan I. Schwartz, who has written for *BusinessWeek* and other publications, describes it thus: "The name *Business Impact* suggests our wider mission. We're broadening our coverage of innovation by following technology beyond the labs into your hands—to the point of impact, where an innovation can become a strategic tool for transforming a company, disrupting a market, or creating an entirely new industry."

Every month, in daily stories, *Business Impact* will examine a different topic. The first month, we analyzed digital marketing; in November, we explore the mobile enterprise, and in December, predictive modeling. *Business Impact* has a novel mode of business. Schwartz explains, "The daily content is free. But at the end of the month, the entire month's stories will be gathered up and designed and packaged as a premium digital publication that will be sold for a fee thereafter."

Last year, in my prescription for saving media, I wrote with pardonably heightened feeling: "Things change or die, including once-cherished organizations. Today's newspapers and magazines will be transformed or replaced by other publications, which will have new modes of business." *Technology Review*'s new designs, and the publishing strategies they express, are our best effort at excellence in our business. They thus represent our best hopes for survival. —*Jason Pontin*

MARK OSTOW



THE INDUSTRY OF SCIENCE

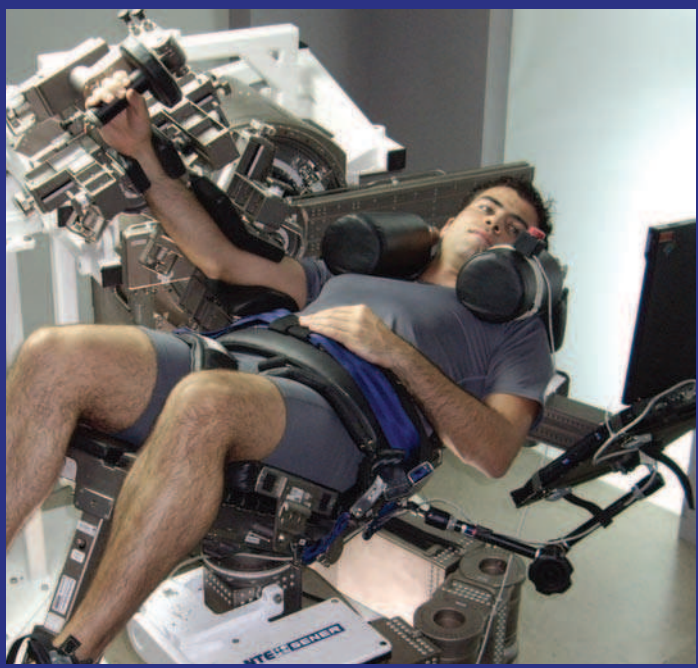
Building scientific research facilities depends upon the expertise and technologies that emerge from the private sector, and Spanish engineering, scientific, and construction companies are making significant contributions to the advancement of knowledge worldwide.

Scientists smash atomic particles to discover secrets of the beginnings of the universe. They fuse the nuclei of atoms in an attempt to re-create the conditions that enflame the sun and furnish it with limitless energy. Researchers build telescopes here on Earth and send satellites out into space in search of a deeper understanding of our planet, our galaxy, and the cosmos beyond. Behind these massive scientific undertakings stand hundreds of companies around the world that strive to meet the needs—and dreams—of the scientific community.

Spanish companies participate in contracts for major scientific installations that are worth more than 420 million euros a year. Manuel Serrano heads the scientific program of Spain's Center for the Development of Industrial Technology, an agency tasked with financing research projects and assisting Spanish companies to reach international markets. "We're always working with companies to innovate, so that instruments for scientific teams will be the ultimate, the most advanced products," says Serrano.

These advances, he adds, can extend beyond the project itself: "The development of technology for scientific installations has a very interesting component, that these technologies can also be adapted for consumer products in the future."

PHOTO COURTESY OF IDOM



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EXERCISING WITHOUT GRAVITY

Every time astronauts launch into space, their muscles start to deteriorate. "When we're on Earth, we exercise all day. Just standing up is a form of exercise, because we're supporting our body with muscle groups," says Jordi Duatis, Muscular Atrophy Research and Exercise System (MARES) payload engineering manager with NTE-Sener. "But when you're in microgravity, you're not doing any exercise. You're continuously losing muscle mass."

Astronauts currently exercise about two and a half hours a day while traveling beyond our atmosphere. Scientists wanted more detailed information on exactly what happens to their muscles in microgravity, and whether their exercises are the best to keep them fit. The precursor of MARES, a small system that tests only the ankle and elbow joints, couldn't fill in the gaps about a whole range of muscle groups.

To delve into these questions, and to help devise a plan to maximize astronaut fitness, the European Space Agency (ESA) began the MARES project together with NASA, using NASA's Human Research Facility. NTE-Sener, which won the contract for the system, began developing the concept about fifteen years ago.

Working in close coordination with ESA and with the astronauts themselves, NTE engineers created a tool with more than 100 different mechanical elements that can be combined in different configurations to isolate 11 different muscle groups and test them against specific forces and in various modes of muscle contraction.

The astronauts strap themselves into an adjustable chair that includes levers, connectors, pads, and handgrips. "It's like a contest between you and the machine," says Duatis. All the information from the tests is fed to a laptop.

Astronauts visited the Barcelona test facility throughout the development of MARES to try it out, from the beginning of the design phase through the final product; it is up to the astronauts to assemble the system in space. MARES was launched in April 2010 inside a logistics module to the International Space Station. After all the tests are done to ensure that the motor, the sensors, the safety devices, and all other mechanical parts are working perfectly, the first scientific experiments are expected to begin by spring 2011.

OUT-OF-THIS-WORLD DESIGNS

Machinery that circles the heavens, training its gaze either on Earth or out towards the stars, needs to be first tested and validated on solid ground. Spain's Telstar group of companies includes Telstar Vacuum Solutions, which capitalizes on its knowledge of vacuum systems to design test chambers for spacecraft.

"A satellite has to be tested in an environment that simulates the space environment," says Ferran Costas, director of Telstar Vacuum Solutions. "This means you need to re-create a vacuum, with extreme temperature ranges from -190 °C to up to 180 °C."

The chambers the company designs can reach the necessary ultrahigh vacuum conditions and endure the wide temperature swings, and range from small spaces to test individual pieces of electronic equipment, to large rooms for observation satellite instrumentation.

Sener, an engineering company, began working in the space sector more than 40 years ago, even before the creation of the official European Space Agency (ESA). The company developed the Kiruna launch base in Sweden, and has "the capability to build any moving part in a satellite," points out Diego Rodriguez, director of Sener's space division.

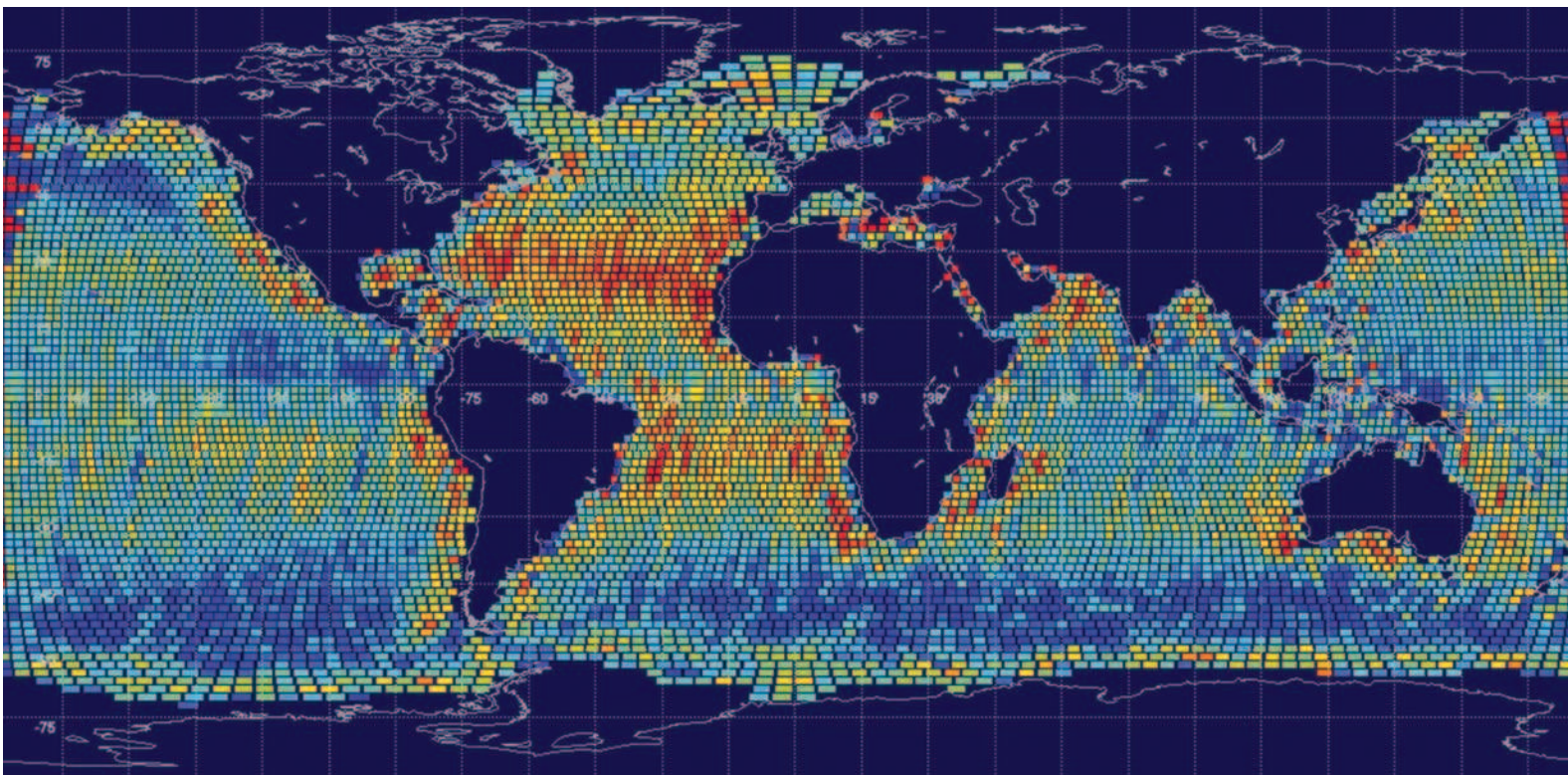
The company is currently working on building a sun shield for the telescope for the new ESA satellite Gaia. Gaia's sensitive telescope is destined to help create a three-dimensional map of our galaxy. "The telescope has to be protected from the sun, with a large 11-meter diameter umbrella," says Rodriguez, "and that umbrella has to be deployed once the satellite is in space."

The need for a sun shield introduces a number of complications, such as how to store an element that large in as small a space as possible, adding as little weight as possible, while ensuring that its mechanisms and material won't be affected by swings in temperature and that it will deploy in space without incident. "This is an important failure point—if we do not deploy properly, we'll lose the mission," he explains. Sener is now in the process of evaluating the sun shield deployment in ESA's test chambers.

For NASA, Sener built the antenna-pointing mechanism used in the new Mars Rover. "On Mars, mechanisms suffer because the dust is so thin, it gets everywhere and gets mixed up with lubrication," Rodriguez describes. "The best [plan] is to protect junctions with a flexible material that can follow movement but seals the whole junction." For a future European Mars rover, Sener is also designing a drill.

Indra, a Madrid-based international technology company with about 30 thousand employees, has a division devoted to space. For the ESA satellite that measures ocean salinity—it's named Soil Moisture and Ocean Salinity (SMOS)—Indra led a team responsible for building the hardware and software for ground stations and for data processing centers, dedicated to receiving data from the satellite and making it accessible to scientists. The satellite was launched last November.

Mier, which began working in antennas more than a half century



Above: Indra's Soil Moisture and Ocean Salinity (SMOS) satellite maps global ocean salinity. Changes in the concentration of salt in the oceans drive the currents that help regulate the climate of our planet.

ago, began to develop applications for telecommunication and research satellites 25 years ago. "The base of our technology is related to high-frequency radio-frequency microwave applications," says Pedro Mier, president and CEO. Mier's antenna technology can be used for amplification of extremely low signals.

The scientific team of the SMOS mission needed to identify and measure gradients of signals that are produced by changes in soil moisture or ocean salinity. Mier designed both the microwave sensor that can receive these low signals from thousands of miles away and the signal processor to extract the data. "We worked with ESA for ten years to develop three different versions of the technology, and then finally we worked on the construction of the satellite itself," says Mier.

The satellite has provided the first-ever global map of ocean salinity; this is relevant for climate change research, as changes in the concentration of salt in oceans drive the currents that help regulate the globe's climate. The first maps from SMOS were presented at ESA's Living Planet Symposium in Norway in June 2010.

For Galileo, the European satellite navigation system, Indra built ground stations all over the world, and developed the processing software in those stations. The antennas, monitoring systems, and control software allow Indra engineers to process Galileo's information in real time. In order to create highly detailed maps that will allow planners on local, regional, and national levels access to comparable information from city to city, Indra is also participating in a project that will use observational satellites (along with planes that fly over cities) to send out signals and, based on the signals sent back, aggregate complete information about land use. The goal is to map the 500 largest urban areas in Europe.

AN EYE TO THE SKY

Added Value Solutions, or AVS, develops machines known as mechatronics—large pieces of equipment that combine mechanical features with electronics—to operate both in space and in extreme research conditions, able to withstand vacuums, radiation, cryogenic temperatures, and high magnetic fluxes. AVS technologies supply particle accelerators and fusion research facilities across Europe.

AVS recently developed a novel method of observing the heavens from Earth. Telescopes pointed at the sky have fibers that are controlled to focus on a given point. "You divide [a] one-meter diameter of a focal plane into very small cells in which you have to move a fiber, and this movement follows an object in the sky," says Miguel Angel Carrera, director of AVS. "So if you divide the plane into a thousand fibers, that means that in a single exposure, you can actually follow a thousand objects in the sky, tracking them and compensating for the movement of the Earth against the sky."

PHOTO COURTESY OF INDRA

An Interview with Miguel Angel Carrera,

Director of the Spanish Association for the Industry of Science (INEUSTAR)

INEUSTAR was founded in March, 2010 to promote companies involved in scientific research facilities. "Collaboration, alliances, continuous innovation and a hunger for excellence are the driving forces of the new organization," states Francisco Javier Cáceres, international technology expert and one of INEUSTAR's founders, together with the Spanish innovation agency Gipuzkoa Berritzen-Innobasque.

Miguel Angel Carreras, CEO of Added Value Solutions (AVS) and INEUSTAR's first director, points out that the scientific research sector is a multibillion dollar industry, with projects that span continents and last for many years. It offers Spanish companies the opportunity to work on the frontiers of science and technology and to develop systems that could eventually provide an advantage in the commercial market.

What's the role of INEUSTAR for companies in the scientific industry?

Carrera: INEUSTAR is meant to be a tool for companies and scientists to get acquainted with each other. Companies have to understand what will be needed in the scientific industry, and researchers need a map of companies and their capabilities. The organization is intended to help scientists choose the best options in Spanish industry, and to help Spanish companies choose the most promising research projects.

INEUSTAR is also working alongside the Spanish government, which contributes to major scientific facilities. These projects demand collaboration among many countries, and this can take the form of either cash or in-kind donations. But to give in-kind donations, a country has to have an industry that is prepared to meet the needs of top research facilities. So the aim of INEUSTAR is to help the government prepare companies for both the medium and long term to provide services at the top technological levels.

Spain has a significant tradition in industry, and Spanish companies and industries have been quick to change from one technology to another as demands change. For instance, Spain formerly was one of the biggest players in building ships and boats. This industry has since closed, and now companies are providing technology for aeronautics and the aerospace industry. And they're developing new technologies to meet the needs of the most advanced international scientific centers.

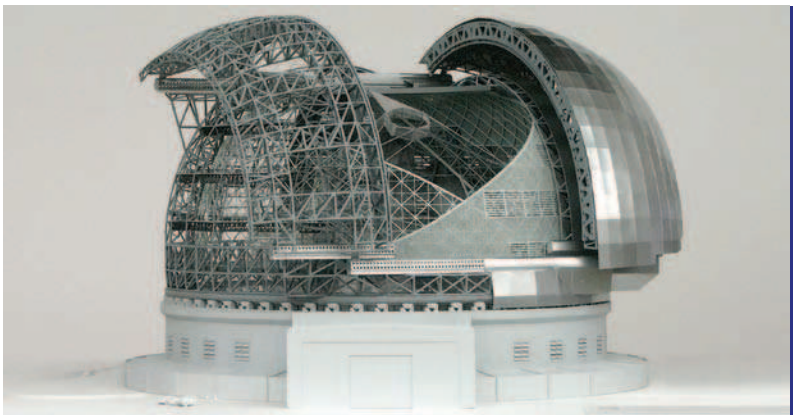
Read complete interview at www.technologyreview.com/spain/ios

AVS developed a new robot to position those fiber planes and divide the focal plane into eight thousand points of focus. The AVS solution improves on a similar technology developed at the Lawrence Berkeley Laboratories. AVS will be working with Berkeley Lab to present the new system to the U.S. Department of Energy in the fall to apply for funding.

Fractal, which was founded by Marisa Vargas, a former university professor, first consulted for the large telescope on Gran Canaria, the Gran Telescopio de Canarias (GranTeCan), heading a group in charge of some of the project's instrumentation. Vargas formed the company because, as she explains, "there aren't big multidisciplinary engineering groups within universities that can make [the] complex instrumentation needed for science." Fractal builds bridges between scientists and engineers by assisting in converting scientific ideas into useful machines. In one of its latest projects, Fractal is working with a university in Madrid on the management and design of spectrographs (through which light is split into different wavelengths), proposed for the GranTeCan telescope.

One main concern in manufacturing for such large, expensive facilities is the durability of materials. Cryobest has mastered a technique whereby components are treated at cryogenic temperatures— -180 °C—that alter the crystal structure of metals to increase wear resistance, stability, toughness, and conductivity. This technique is unusual in that it involves multiple stages of dipping below -180 °C, instead of a one-time multiday cryogenic freeze. "This process is more efficient; you can achieve the same or better results in 12, 13 hours instead of 20 to 30 hours," says Luis Angel Alava, president and CEO of the company. Cryobest used this technique to treat large aluminum components known as optical beds for an ESA telescope launched last year.

Cadinox, a family company founded in 1956 that does welding and machining for industrial processes, began working on local Spanish scientific research projects, then expanded into larger scientific installations. "We use advanced processes for cutting raw mate-



Building the structures to house major telescopes requires complicated engineering. Engineers at Idom are currently working on the housing for the European Extremely Large Telescope, the largest optical telescope in the world, to be located on a mountain in Chile's Atacama desert.

rials and for welding. For example, [for] the tanks that are under vacuum pressure, the requirements for the welding and machining are quite strict," says Andoni Isasti, director of Cadinox. So the company performs surface and ultrasonic tests to avoid any crack or fault in the welding. "This is artisanal, handmade work," Isasti continues. "Our experience and our knowledge mean that we know how to manufacture what our customers need."

Building the structures to house major telescopes requires complicated engineering. Idom, with more than 2300 employees, has an entire business division devoted to advanced solutions, particularly for scientific structures. "Scientists are always challenging and demanding state-of-the-art solutions, so we don't usually have a product designed [and ready]. You always have to look for new solutions," says Amaia Zarraoa, principal engineer of Idom's division of advanced design and analysis.

Company engineers are currently working on the housing for the European Extremely Large Telescope, the largest optical telescope in the world, to be located on a mountain in Chile's Atacama desert. About 250 feet high and about 260 feet in diameter, this telescope will be encased in a rotating building, the door of which will allow light to stream in to its mirrors. "This is a 6000-ton building, and the whole building moves. The challenge is designing mechanisms for the rotation within the accuracy needs of the telescope, and so that the enclosure avoids disturbing the telescope in any way," says Gaizka Murga, business development manager for Idom's astronomy projects. "We have to be able to move the whole structure within the accuracy of millimeters." Idom was recently awarded a contract to work on the Advanced Technology Solar Telescope, which is to be built on Maui.

Belarmino Feito founded his company, Asturfeito, as a one-person repair shop in the industrial, iron-producing region of Asturias in northern Spain, and has worked his way up to subcontracting for industries such as defense and mining. In 2000, with many employees working for him and extensive experience in a variety of sectors, he began expanding out of Spain and into other countries, including France, Switzerland, and Germany. About two decades ago he set the stage for producing parts for the Large Hadron Collider by increasing the complexity and precision of his operations.

Asturfeito now has contracts for NASA's space institutions and for manufacturing antennas for a new telescope in Chile called ALMA, one of the largest telescopes in the world. "These require a great deal of know-how and precision," says Feito. "The antennas can weigh more than 70 tons."

EXPLORING THE UNIVERSE'S ORIGINS

Hidden 300 feet beneath the Earth's surface, and looping for seventeen miles, the Large Hadron Collider flings subatomic particles around a race track at nearly the speed of light and smashes them against one another to explore the secrets of the universe's beginnings. The LHC, built by the European Organization for Nuclear Research (CERN), took 16 years and $10 billion to complete. Its first particles began colliding in the spring of 2010.

This machine, the world's largest collider, demanded extraordinary precision from its suppliers to meet its exacting standards. The tubes through which the particles fly are kept in ultrahigh vacuum conditions to avoid the entrance of any stray particles of gas. The entire system is cooled to -271°C, colder than outer space, while the temperatures generated by colliding particles may become more than 100 thousand times hotter than the temperature of the sun's core.

Companies from around the world have supplied parts and expertise for the LHC, among them 35 Spanish companies. Scientific research facilities generally work with companies who have already proved themselves through work with other similar facilities. Spain's DMP, founded in 1999, had developed a core business machining parts for the aerospace market, which demands extremely high precision. "So within the world of the aerospace sector, we have created a small niche [in] manufacturing very difficult segments," says Philippe Roulet, marketing director.

"We saw that the field of scientific installations also needs extreme precision parts," says Roulet. So he contacted a purchaser for CERN in Geneva. "He said, 'Sorry, we're not interested in the aerospace market, because there isn't the precision we need.' I insisted, and sent images of difficult parts that we were making," recounts Roulet.

Roulet's persistence paid off. CERN's purchasing team sent DMP plans for a small part, very difficult to machine, which only

PHOTO COURTESY OF IDOM

two large German companies had been able to manufacture, using specialized equipment. DMP uses conventional machinery to make them, instead employing advanced metrology, or measurement technology, to characterize any precision losses. Explains Roulet, "We have a really strong understanding of what's happening in the machine, the tools, and the materials, and then we can compensate and correct to guarantee the final results."

DMP was able to machine the parts with the same precision as the larger German company at a lower cost, and was soon commissioned to make additional parts for the collider. "We're a smaller company, working in the Basque country in Spain. But now, with important references such as CERN, we can immediately capitalize on this experience."

Elay, a machining company that mainly produces tools and parts for the automotive sector, was one of three companies around the world that could develop parts by a process called fine blanking to produce about 8 million parts for CERN (40% of the total volume). Swisslan, a machining company with expertise in high-precision, difficult parts "that other companies don't want to do," according to its founder Angel Ibarluzea, is manufacturing a number of parts for CERN experiments, advanced, complex components, made of pure copper. And Antec, also based in the north of Spain, designs and manufactures both normal-conducting and superconducting magnets for international particle accelerators.

On a curved track such as the one at the LHC, superconducting magnets create an electromagnetic field that forces the particles to follow the planned trajectory. "Normal-conducting magnets are not able to create a strong enough electromagnetic field," says Aitor Echeandia, Elytt's business manager. Elytt was formed in 2002 by engineers who had worked on superconducting magnets for major scientific research institutions.

Echeandia continues, "We have to use a number of different technologies. We have strong knowledge in superconducting cables, and also in cryogenics, because superconducting magnets are cooled with helium. And we need to know about vacuum technology. And all of this has to be integrated into the calculations."

The conducting magnets need to be placed with extreme accuracy so that they perform their key function, that of thrusting the particles ahead. Fagor Automation has been engaged in positioning these magnets, using linear encoders, sensors paired with scales that encode and position them with precision measured in nanometers. The encoder's linear scale includes a tiny code on the micron level—similar to a bar code—that is photographed through special optics. That encoded data is translated into information about where the scale, and thus the magnet, is located. "You need very high resolution to move the magnet even the smallest bit, to be able to detect that movement," says Pedro Ruiz, Fagor Automation's general manager. Fagor has been perfecting its linear encoders, which it builds in special isolated chambers that allow nanoscale deposition of materials without disturbances from, for instance, outside vibrations.

RE-CREATING THE SUN

Elytt's experience manufacturing superconducting magnets for the Large Hadron Collider placed it in an ideal position to enter a consortium to manufacture and supply superconducting coils for a new fusion project, the International Thermonuclear Experimental Reactor, or ITER, to be built at Cadarache, in the south of France. The multibillion dollar project will be the world's largest fusion experiment, with contributions from the European Union, the United States, Russia, and Asian countries. ITER will attempt to re-create the conditions of the process that powers the sun, in order to manufacture a potentially endless supply of renewable, carbon-dioxide-free energy.

Magnetic fields contain the plasma away from the chamber's walls. To create these fields, the project demands superconducting coils larger than any that have ever been produced. Each coil is about 48 feet long and 18 feet across and weighs approximately 300 tons. The consortium's leader, the Spanish power company Iberdrola, will oversee design and development and take charge of quality control and construction. Elytt is pairing with the Italian company ASG Superconductor on research, design, and manufacturing. The first phase alone—research and development to produce a mock-up—will take between two and three years, according to Echeandia. Echeandia estimates that the final manufacturing, five to seven years from now, will demand about ten different manufacturing steps.

Creating the magnetic field also requires an electrical current to be driven through the plasma. The extreme power needs of this process match the experience of Northern Spain's Jema group, which since 1953 has been providing electronic power equipment, such as secure power systems for power plants, and advanced systems for laboratory applications, including fusion reactors and particle accelerators. In the late 1980s, the company delivered the first solid-state high-voltage power supply for the Spanish government's fusion research laboratory, feeding plasma heating for the experimental fusion reactor. They were then able to continue on to other fusion laboratories in Europe. Says Francisco García, Jema's engineering manager, "For these highly skilled technical projects, the markets are limited to only a few potential suppliers. The number of references is key for accessing new clients."

Jema most recently completed four high-voltage 17-megawatt supplies for plasma heating for the Joint European Torus (JET) experiment in the United Kingdom, the largest nuclear fusion experiment to date. "The chamber where the hydrogen is confined, you have to get it to a very high magnetic confinement at very high temperatures to produce the fusion reaction," García explains. "You need strong magnets that have to be fed by very strong power supplies." At the same time, he continues, "If you're injecting a huge amount of power, like 20 MW, you need to be able to stop in microseconds, which is a very demanding requirement." To do so, they take power from the grid, store it and then pass it through different stages to get to the power and current that the

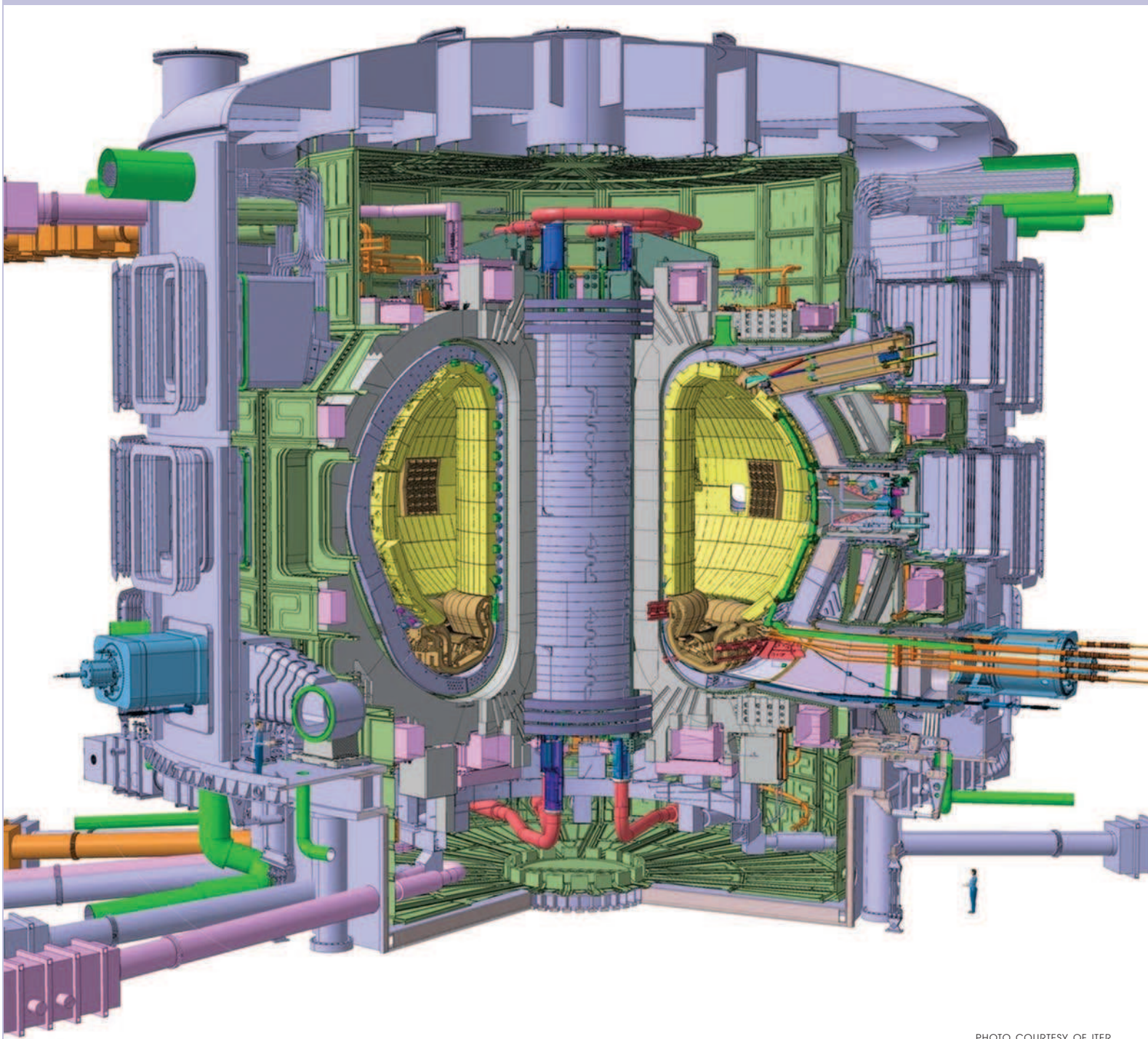


PHOTO COURTESY OF ITER

Revolutionary Reactor

This is a graphical representation of the International Thermonuclear Experimental Reactor, or ITER, which will be the world's largest fusion experiment. ITER will attempt to re-create the conditions of the process that powers the sun, in order to manufacture a potentially endless supply of renewable, carbon-dioxide-free energy.

customer requires, so that it can be delivered and stopped at quick command.

Jema's experience in fusion reactors throughout Europe positions it to apply for the contracts to provide power to the ITER's new facility. "This will be the second-biggest scientific cooperative project in the world, behind the International Space Station. As we have many references in fusion, we're focusing our next target on ITER itself," says García.

ITER's ultrahigh vacuum prevents any stray particles from interfering with the reaction. Within the reactor, special containers will be positioned to capture byproducts of the fusion reaction. The research team needed a company to build robots to enable the remote handling of these containers; Telstar, with its experience in vacuum containers to test space technology, won the contract to design, manufacture and supply these robots.

"The unit has to manage a load of nearly 10 tons, and has to operate in a vacuum without breaking the vacuum of the ITER vessel," says Telstar's Costas. "They also have to withstand heavy radiation from the thermonuclear fusion; there's a radioactive environment inside the vessel even when the fusion reaction is stopped." One example of this problem and its solution: most oils used in hydraulic equipment can't withstand this radiation, so for ITER, Telstar is using water-based lubricants.

One potential goal of ITER is to replace nuclear power generation, and large companies that work with nuclear power have been able to supply a great deal of the necessary experience to design ITER's buildings and systems and to help determine the safety procedures. Empresarios Agrupados, founded in 1971, was created as an engineering company to serve the nuclear industry. "Apart from building the Spanish nuclear power plants, we've now been involved in all the new nuclear reactors in Europe," says Teresa Dominguez, advanced projects manager of Empresarios Agrupados. The company's background in filling the engineering needs of such large and complex structures gave it the experience to take on designing buildings for the ITER facility and calculating the electrical distribution system for the experimental fusion power plant.

Many Spanish companies working in fusion first delved into that sector via Spain's National Fusion Lab, which began research in the early 1980s in partnership with the U.S. Oak Ridge National Laboratory. Spain's reactor was built by the mid 1990s, with about 60 percent of the contracts awarded to Spanish companies. "At the time, those contracts were not the ones requiring the highest level of technology," says Joaquin Sanchez, director of the Fusion Lab. "They were for more accessible requirements, such as the electrical equipment and the buildings."

But after acquiring experience in Spain, many of those companies moved on to compete for projects at the European level, with increasingly higher levels of technological complexity. "They became more confident in working in this market; it's no longer new to them," says Sanchez.

The budget for ITER, explains Sanchez, is made up of contributions from member countries, about 15 percent of which is in cash. The remaining 85 percent can be an in-kind contribution—but only if companies have the technological experience and knowledge to meet the requirements. So CIEMAT, the Spanish research organization that directs the country's fusion research, has begun a program of grants to develop new technologies for fusion. "It's not easy to start from scratch and get a contract," points out Sanchez. "It's much better if you're already in the system, and know exactly what the needs are." This has already paid off: in 2010, Sanchez says, the contracts awarded to Spanish companies totaled about 90 million euros.

Resources

ICEX
(Spanish Institute for Foreign Trade)
www.spainbusiness.com
www.spaintechnology.com

INEUSTAR
(Spanish Association of Industry of Science)
www.ineustar.com

Asturfeito
www.asturfeito.com

AVS
www.a-v-s.es

DMP
www.dmp.aero

Elytt Energy
www.elytt.com

Fractal
www.fractal-es.com

JEMA
www.jema.es

NTE-SENER
www.nte.es

IDOM
www.idom.es

For a complete company listing and to find out more about New Technologies in Spain, visit:
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CONSUMER ELECTRONICS

Tablet 2.0

SAMSUNG'S ANSWER to Apple's iPad has a seven-inch screen, up to 32 gigabytes of memory (expandable to 64 gigabytes with a built-in MicroSD card reader), and front- and back-mounted cameras for applications such as videoconferencing and augmented reality. It uses the Android operating system, and unlike the iPad, it will run Flash-based Web applications—so you won't have to give up watching your favorite videos because Mr. Jobs says so. It connects to the Internet over Wi-Fi or cellular networks.

Product: Galaxy Tab **Cost:** About $950 **Availability:** Now **Source:** galaxytab.samsungmobile.com **Company:** Samsung

JOSHUA SCOTT

TRANSPORTATION

Battery Burners

Mass-market electric vehicles are joining new hybrids on the road.

THE I-MIEV has a range of 160 kilometers and can be charged in either of two ways. Fully charging the battery from a regular power outlet requires up to 14 hours, depending on the voltage. Alternatively, a dedicated quick-charging system can provide an 80 percent charge in about 30 minutes.

Product: i-MiEV **Cost:** Under $30,000 **Availability:** Now
Source: www.mitsubishicars.com **Company:** Mitsubishi

THE ALL-ELECTRIC NISSAN LEAF has a range of 160 kilometers and a top speed of 145 kilometers per hour. Owners can remotely access the battery management system to monitor charging or find out how much charge is left in the battery.

Product: 2011 Nissan Leaf **Cost:** $32,780 **Availability:** December 2010
Source: www.nissanusa.com **Company:** Nissan

THE FISKER KARMA is a plug-in hybrid aimed at the luxury market. Its battery carries enough charge for 80 kilometers' worth of driving before the internal-combustion engine kicks in. Running off battery power alone, the car can hit a top speed of 153 kilometers per hour; it can reach 200 kilometers per hour with the aid of the internal-combustion engine.

Product: Fisker Karma **Cost:** Not available **Availability:** Spring 2011
Source: www.fiskerautomotive.com **Company:** Fisker Automotive

THE CHEVROLET VOLT, a plug-in hybrid that can be charged using residential electrical outlets, has a battery range of 64 kilometers. Like the Fisker Karma, it is a series hybrid, meaning that an electric motor is required to turn the car's wheels; when the internal-combustion engine is in use, it drives a generator connected to the motor. In the Volt's case, the engine can also provide supplemental mechanical torque. Other hybrids have parallel designs, in which either the motor or the engine can propel the vehicle alone.

Product: Chevrolet Volt
Cost: $41,000 **Availability:** December 2010
Source: www.chevrolet.com
Company: General Motors

THE FIRST MASS-MARKET electric vehicle from a U.S. car company, the Coda has a range of up to 190 kilometers per charge. It extends the life of the battery by using a thermal management system to optimize its performance for summer and winter weather.

Product: 2011 Coda Sedan **Cost:** $44,900 **Availability:** December 2010 **Source:** www.codaautomotive.com
Company: Coda

COURTESY OF MITSUBISHI; NISSAN; FISKER AUTOMOTIVE; GENERAL MOTORS; CODA

LIFESTYLE

Go Nowhere—In Style

FINALLY, an exercise bike that doesn't have to be hidden away when guests visit. The cycle's body is made of carbon composites, fiberglass, and steel. An epicyclic transmission connects the pedals to a flywheel concealed within the large outer ring; resistance during workouts is generated by an electromagnetic system. The only problem: given its price tag, your guests might have to help with some generous donations.

Product: Ciclotte **Cost:** Around $11,000 **Availability:** Now **Source:** www.ciclotte.com **Company:** Ciclotte

BIOMEDICAL

Pill Pusher

A SMART plastic cap helps patients take medication when they are supposed to. The cap, which can be fitted to standard prescription bottles, flashes and plays a ringtone when it's time to take a dose. If a patient misses those cues, it sends a signal to a receiver plugged into a wall socket, which has the system call the patient's phone with a reminder. The system can also send reports to family members and the patient's doctor, and it can contact the pharmacy when a refill is needed.

Product: GlowCap **Cost:** Free to participating pharmacy customers **Availability:** Now **Source:** www.vitality.net **Company:** Vitality

COURTESY OF CICLOTTE (BIKE); CHRISTOPHER HARTING (PILL CAP); AT&T (PHONE)

COMMUNICATIONS

Satellite Smart Phone

DURING the 1990s, many believed satellite phones were the future of mobile communications. Rapidly expanding terrestrial cellular networks gobbled up most of the market instead. Still, satellite phones retained some technical advantages over cellular ones, principally in remote or rugged areas that are difficult to cover economically with cell towers. Now the TerreStar Genus smart phone is combining the best of both worlds, using a cellular connection when available and tapping into a satellite feed when people wander out of range of a cell tower.

Product: TerreStar Genus **Cost:** $799 **Availability:** Now **Source:** www.att.com **Companies:** TerreStar, AT&T

RULE THE AIR

I CAN'T CONTROL EVERYTHING, BUT I'M GETTING DANGEROUSLY CLOSE.

You have teams spread all over the world. Keeping them all on the same page takes a lot of coordination. With a unified communication solution from Verizon, you can stay connected to your teams regardless of their location. So while your projects may be complex, your collaboration is anything but.

VERIZONWIRELESS.COM/TECHNOLOGY

verizon

Network details & coverage maps at **vzw.com**. © 2010 Verizon Wireless.

BIOMEDICAL

Where's the Scalpel?

SURGEONS sometimes leave instruments or sponges inside their patients, typically necessitating a second surgery to retrieve these inadvertent souvenirs. A new system uses portable antennas located around the operating table that read button-size RFID tags attached to the items used in surgery. This automates the tracking process, so that physicians preparing to sew a patient up can be sure nothing's been left behind.

Product: ORLocate **Cost:** $99,500 per operating room **Availability:** Now **Source:** www.orlocate.com **Company:** Haldor Advanced Technologies

CONSUMER ELECTRONICS

Heads Up

MOST augmented-reality applications run on handheld devices *(see "Tablet 2.0," p. 25)*, but these glasses can create a hands-free digital overlay on the user's world. Two stereo cameras mounted in the front of the glasses feed a 3-D image to a computer that adds digital imagery to the scene. The result is then piped to the wearer by displays in the glasses.

Product: Wrap 920AR glasses **Cost:** $1,995 **Availability:** Now **Source:** www.vuzix.com **Company:** Vuzix

CONSUMER ELECTRONICS

Couch Keyboard

THERE'S STILL a lot of confusion about the best way to combine social media and Internet video services with the traditional television experience. The Boxee Box is an Internet-enabled multimedia jukebox that offers one way to interact with websites that were originally designed for computer users (such as Facebook and Twitter): a QWERTY keyboard is built into the back of the remote control.

Product: Boxee Box **Cost:** $200 **Availability:** Now **Source:** www.boxee.tv **Company:** D-Link

COURTESY OF HALDOR ADVANCED TECHNOLOGIES (ORLOCATE); CHRISTOPHER HARTING (GLASSES, BOXEE)

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Accelerating Enterprise Transformation with Architecture-Driven Modernization

Artificial Intelligence (AI) is the quest to achieve computers that equal or exceed human performance on complex intellectual tasks. A phenomenal development in AI is the recent emergence of automated computer language translation programs driven by the need to modernize the nearly half trillion lines of legacy software developed during the latter half of the 20th century.

Early software translations of the 1990s like the earliest chess programs were disappointing and limited. Leveraging AI technologies that evolved from the 1980s era USAF's Knowledge Based Software Assistant (KBSA) and emerging standards, computers can now understand and translate software applications with levels of proficiency that vastly exceed human performance. This technology is revolutionizing the way finance, healthcare, military, and governments modernize their legacy systems.

Leading this field is The Software Revolution, Inc. (TSRI), a Kirkland, Washington based company. Building upon 32 years of continuous R&D, TSRI's robust *JANUS* Studio® tool suite provides large-scale, error-free legacy system modernizations at 100% levels of automation. By applying AI to abstract software models, TSRI delivers automated code conversion with unprecedented target code quality, economies of scale and schedule compression, accomplishing with small teams in months what use to take years.

Many groundbreaking TSRI projects are documented in the OMG Series book aptly titled, Information Systems Transformation: Architecture Driven Modernization Case Studies by William Ulrich and Philip Newcomb (TSRI's founder), Morgan-Kauffman, 2010. This book is a compelling 'How To' guide for conducting modernization projects, a few examples of which are listed below:

Above: Eurocat control station

- **Eurocat - European Air Traffic Management System for Thales Air Systems:** 2+ million lines of Ada into Java, being deployed to 280 airports.
- **Advanced Field Artillery Tactical Data System, U.S. Army and Stanley Techrizon:** 7 Million+ lines of Ada into Java, completed in 10 months.
- **Patriot Missile - Fire Platoon Simulation & Battalion Simulation Support Systems for Raytheon:** 600 Thousand lines of FORTRAN code into C++.
- **A Major Health Care Insurance Company:** 2+ Million lines of PowerBuilder and MAGNAX into JSP and Java.
- **A Major US Bank:** 5+ Million lines FORTRAN to Java *Transformation Blueprint*™.

Philip Newcomb
Founder and Chief Executive Officer, The Software Revolution, Inc (TSRI)

Mr. Newcomb is an internationally recognized expert in the application of artificial intelligence and formal methods to software engineering. After leaving Boeing he led a team of software engineers to develop TSRI's acclaimed ADM services and *JANUS* Studio® toolset. Mr. Newcomb is the author of numerous papers books and industry standards.

TSRI is a Platform Member of the OMG and leading contributor to the ADM task force standards. TSRI's services and *JANUS* Studio® toolset have served as the leading exemplar for the OMG's emerging ADM TF standards.

For more information visit www.tsri.com

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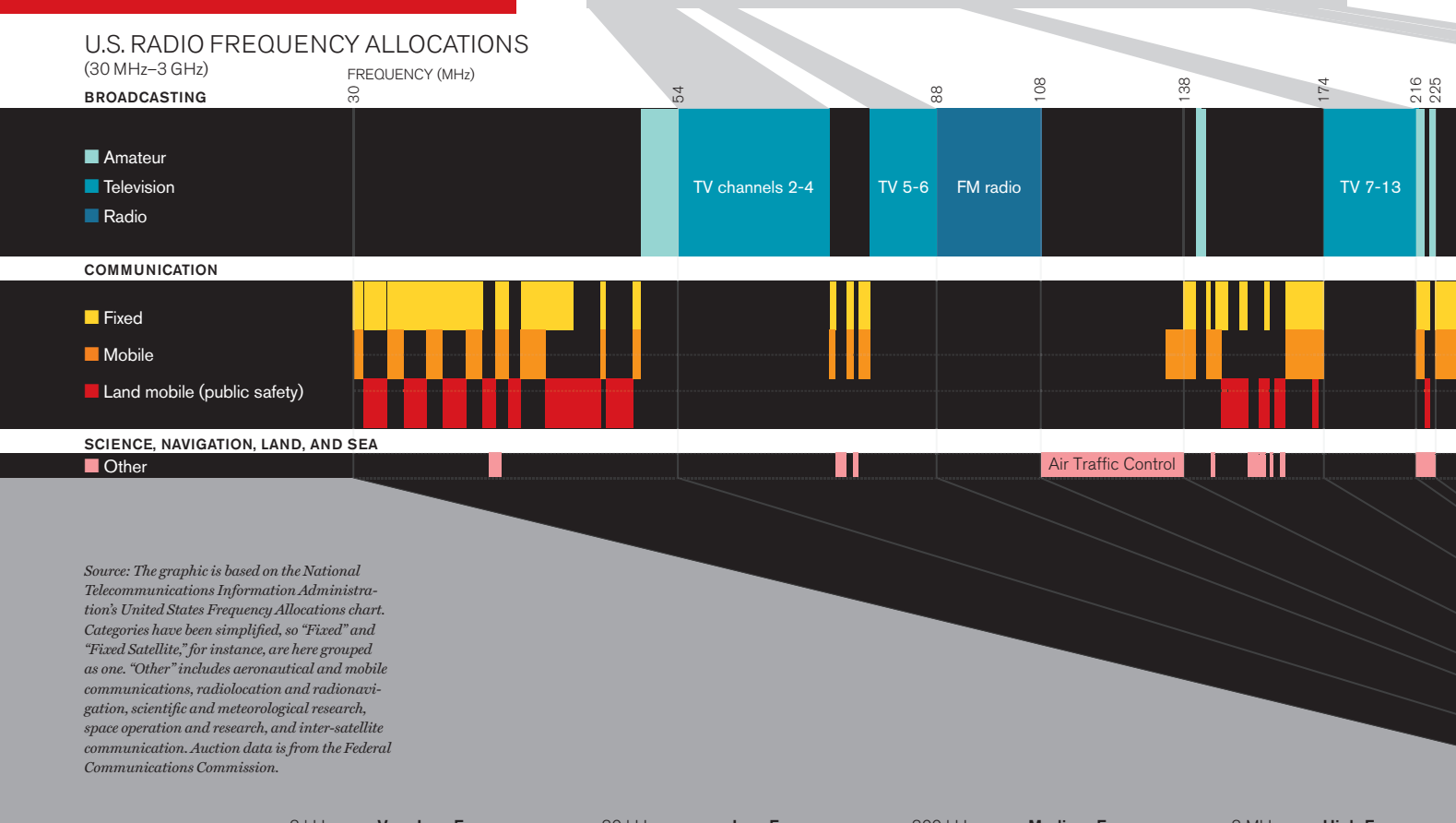
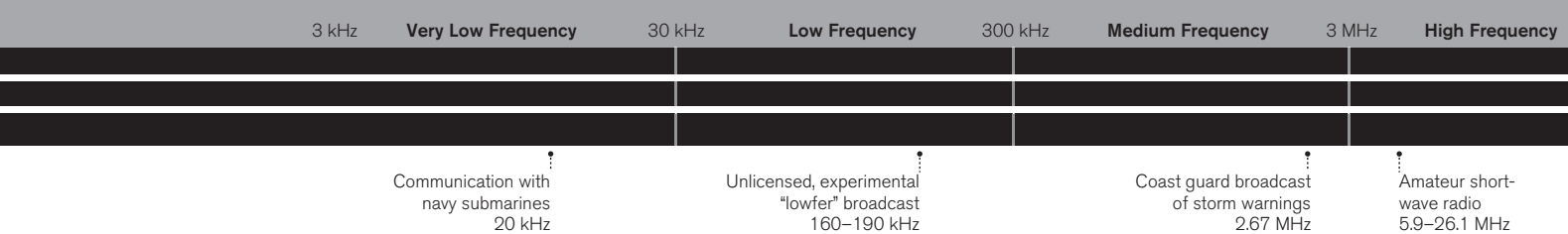
graphiti

OPENING UP "WHITE SPACES"

Even before the switch to digital TV, broadcasters were using less and less of the bands that they had been granted decades ago. These frequencies are especially valuable because they can be used to transmit information over long distances.



Source: The graphic is based on the National Telecommunications Information Administration's United States Frequency Allocations chart. Categories have been simplified, so "Fixed" and "Fixed Satellite," for instance, are here grouped as one. "Other" includes aeronautical and mobile communications, radiolocation and radionavigation, scientific and meteorological research, space operation and research, and inter-satellite communication. Auction data is from the Federal Communications Commission.



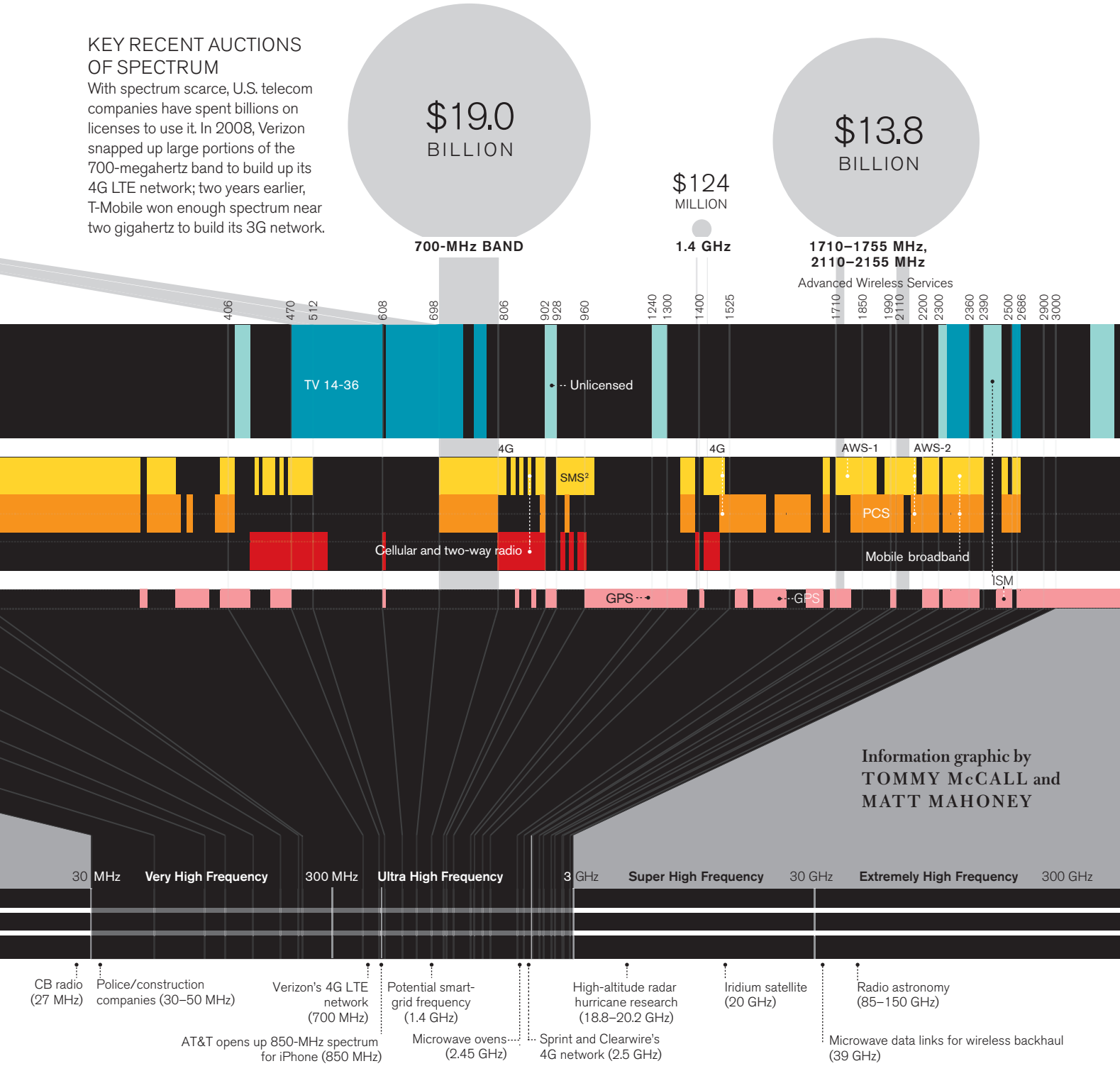
Spectrum of Issues

Increased demand for wireless bandwidth is forcing regulators to get creative.

The radio frequency spectrum, which once seemed to offer virtually unlimited capacity for communication, has become crowded as smart phones and other wireless devices increasingly gobble up bandwidth. One obvious solution has been to let the private sector buy access to underused slices of the spectrum previously reserved for government. In the United States, auctions for those licenses have been going on since 1994; in recent years, these multibillion-dollar spectrum auctions have allowed telecommunications companies such as AT&T, Verizon,

KEY RECENT AUCTIONS OF SPECTRUM

With spectrum scarce, U.S. telecom companies have spent billions on licenses to use it. In 2008, Verizon snapped up large portions of the 700-megahertz band to build up its 4G LTE network; two years earlier, T-Mobile won enough spectrum near two gigahertz to build its 3G network.



Sprint, and T-Mobile to improve 3G networks and build their faster next-generation networks. But in September, the Federal Communications Commission gave its final approval to a potentially more revolutionary policy. It allows certain wireless networks to provide broadband services over the so-called "white spaces," unused areas between stations in the TV broadcast spectrum. Vastly more white spaces are available now that TV broadcasters have switched from analog to digital transmissions. The exact details of how wireless devices will know if a channel is unoccupied and available for broadcast in a particular area are still being finalized. But if the experiment works and more wireless devices can peacefully share the public airwaves, it could lead to a much more efficient and flexible use of the entire spectrum. tr

Q&A

Lawrence Lessig

An advocate for free expression worries that a key Web principle is withering in Washington.

The concept of "network neutrality" was meant to have been woven into Internet regulations by now. Here's the idea: the networks that deliver the Internet to consumers must be equally open to all data packets, no matter whether these are part of an e-mail from your mother or a video from Hulu. It means that Internet service providers can't favor traffic to and from certain companies while undermining competitors' traffic. President Obama supports the principle, and it had momentum even before he took office: in 2008, the Federal Communications Commission sanctioned Comcast for interfering with Internet subscribers' use of BitTorrent, a file-sharing application.

Yet net neutrality is faltering. This year, Comcast persuaded a U.S. appeals court that the FCC overstepped its authority when it enforced net neutrality as if it were law. Meanwhile, one of net neutrality's strongest backers, Google, has stopped insisting that the principle apply on wireless networks, which might need to manipulate traffic to deal with capacity constraints *(see Briefing, p. 67)*.

This disturbs Lawrence Lessig, a net-neutrality advocate who directs Harvard's Edmond J. Safra Center for Ethics. *Technology Review*'s deputy editor, Brian Bergstein, asked Lessig why he thinks innovation on the Internet is at risk.

_TR_: What's the benefit of net neutrality for everyday Web users?

Lessig: It's really important to recognize the accident of the Internet. A bunch of geeks, for a purpose that had nothing to do with Google or Microsoft, decided to make it so that different platforms could communicate. They wanted to find a neutral platform. They couldn't control it; it would develop as the users wanted it to. Little did they know, but they had created the perfect environment for innovation. Because innovators know that if they develop the next great widget, then they can deliver it and they don't have to get permission.

How should the government enforce this?

Have regulations aimed at blocking certain kinds of business models. The right kind of [Internet] infrastructure owner is interested in sending as many bits as fast and as cheaply as possible. He's not interested in "What special deals can I strike with Hollywood so that I can leverage my power to great profit on top of whatever I am selling my bits for?" He is like the electric company: just interested in the cheapest way to deliver the commodity to customers. The problem is, when you give network owners quasi-monopoly power, they think, "I don't want to be in the commodity business. I want to be in the business where I can create an artificial control or scarcity and make lots more money."

But if ISPs were just commodity businesses, would they have enough incentive to develop their networks?

What we've seen internationally is an explosion of companies competing to provide a commodity, just as we saw in the United States when "open access" rules [which once forced network operators to lease their wires to competitors] encouraged a world of 6,000 ISPs. If private incentives to provide public infrastructure are not sufficient, however, then we need to think about more incentives. They could be the sort of subsidies that have supported infrastructure since time immemorial. Interstate highways and Internet networks are essentially the same thing.

Should my ISP be allowed to charge me more if I use a lot of bandwidth?

Yes.

That fits with the electric-company analogy.

Exactly. I do have a problem if the carrier is saying, "Okay, YouTube or Blip.tv, you're going to have to pay a certain amount to have access to [the customers on] our network." We've seen this again and again in history. A new technology shakes up a marketplace. Then there's a period of amazing, generative competition. And then it gets consolidated and taken over, often through a conspiracy with the government that produces concentrated monopoly industries. Radio is the best analogy.

Would it be that sinister if AT&T occasionally delayed videos to iPhones in a busy area to ensure that subscribers there could make voice calls?

Content-neutral or company-neutral interventions are not a problem. They're not ideal, but if you say, "We're at a peak capacity mode, and we're going to throttle all high-[bandwidth] things for this period of time," that's not troubling from the perspective that I'm concerned with. Because you're not striking any special deals with anybody. But the fact that you've got [capacity] problems shouldn't mean that you just say, "Therefore, we're just not going to worry about anything that goes on in this space." The reality is, the future is wireless.

U.S. regulators are reconsidering their approach to net neutrality rules. Are you optimistic that the principle will survive?

I'm not. I think they've lost their window. By delaying, they've just allowed [network operators] to secure the political support they need to block this type of rule. Democrats and Republicans have been reminded of the campaign cash that they get from these entities. tr

Photograph by STEVE MOORS


DANIEL ELLSBERG SECRETS
Slovakia

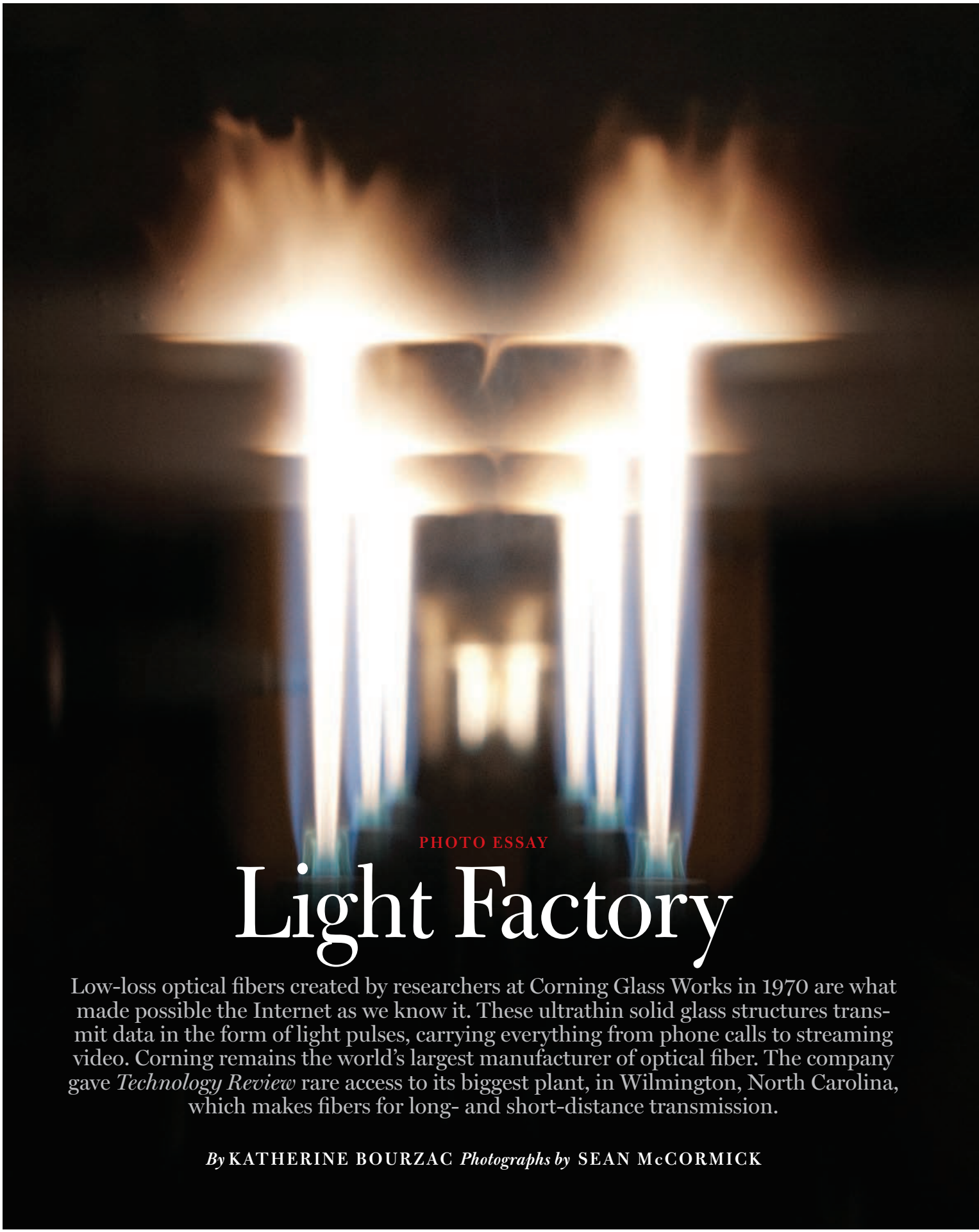


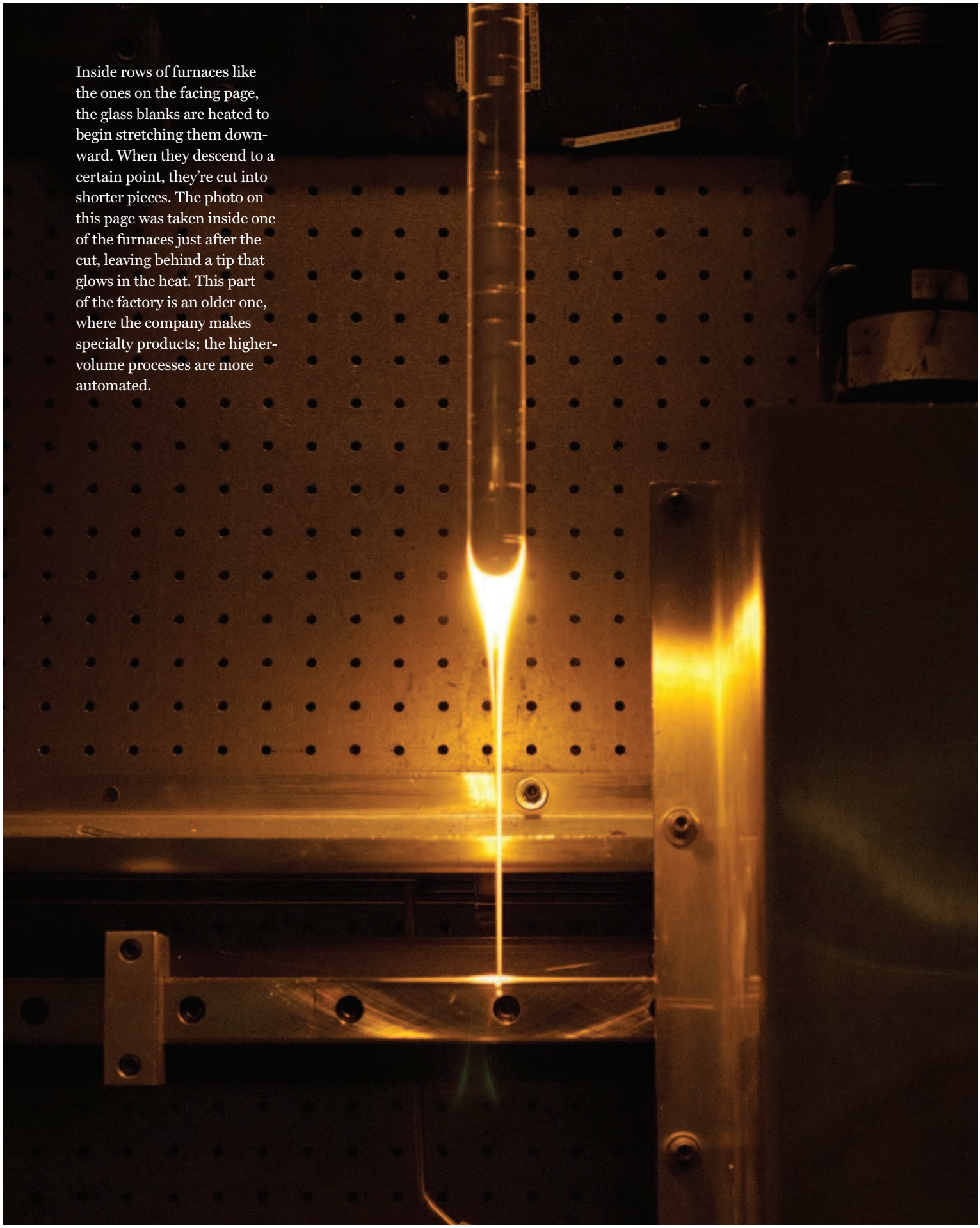
PHOTO ESSAY

Light Factory

Low-loss optical fibers created by researchers at Corning Glass Works in 1970 are what made possible the Internet as we know it. These ultrathin solid glass structures transmit data in the form of light pulses, carrying everything from phone calls to streaming video. Corning remains the world's largest manufacturer of optical fiber. The company gave *Technology Review* rare access to its biggest plant, in Wilmington, North Carolina, which makes fibers for long- and short-distance transmission.

By KATHERINE BOURZAC *Photographs by* SEAN McCORMICK

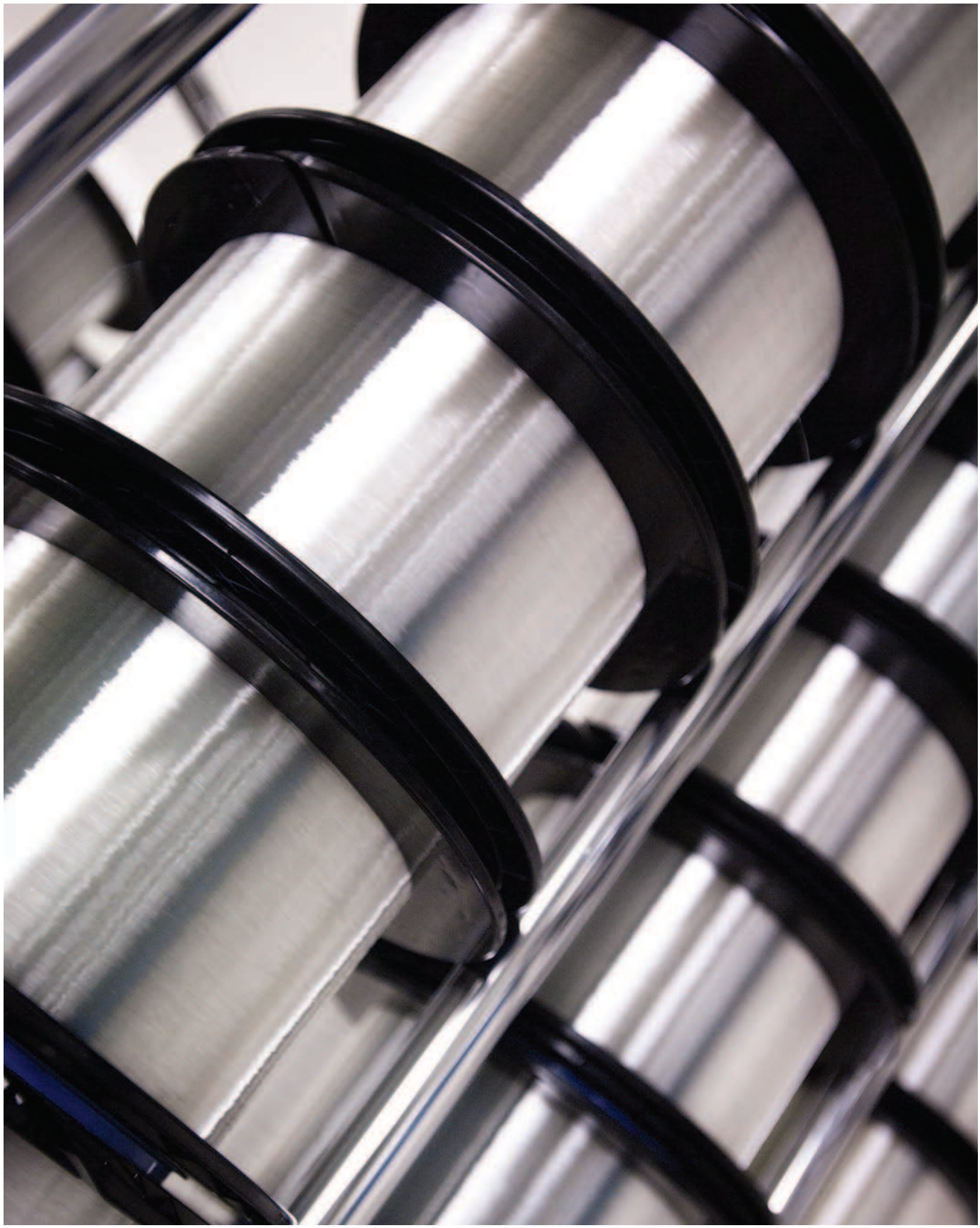
Optical fibers are drawn from large “blanks” like the ones shown here being lifted from holding ovens. The blanks have two layers, both made from silicon dioxide (glass), which will form the basis for corresponding layers in the fiber: a core that transmits light very efficiently and an outer cladding that keeps the light from leaking out. Both the core and the cladding are formed when gas jets inside a high-pressure furnace (facing page) deposit silicon and small amounts of other elements that influence the optical properties of the glass.



Inside rows of furnaces like the ones on the facing page, the glass blanks are heated to begin stretching them downward. When they descend to a certain point, they're cut into shorter pieces. The photo on this page was taken inside one of the furnaces just after the cut, leaving behind a tip that glows in the heat. This part of the factory is an older one, where the company makes specialty products; the higher-volume processes are more automated.

The shortened glass blanks are placed in tall furnaces and heated once more to begin the fiber-drawing process. The first section of glass that comes down is teardrop-shaped (right) and can't be drawn into fiber. A worker quickly cuts it off and lets it fall into a bin like the one on the facing page; this is called "dropping the gob." (In the most up-to-date part of the factory, this step and the rest of the process are automated inside four-story-high furnaces.) After the gob drops, the glass is pulled and stretched by machines that monitor tension on the material to ensure a fiber of consistent quality. The final product is a fiber just a few micrometers in diameter. The ratio of core to cladding remains the same as it was in the glass blank, though each layer is much thinner.

The glass fiber is threaded through tubes (this page) and irradiated with ultraviolet light to harden a protective polymer coating on the surface. The finished fiber is packaged on spools (opposite), tested for its mechanical and optical properties, and shipped out all over the world.



The last decade expanded what we could do online, but the Web's basic programming couldn't keep up. That threatened to fracture the world's greatest innovation engine—until a small group of Web rivals joined forces to save it.

The Web Is Reborn

By BOBBIE JOHNSON

The Web has been showing its age.

Superficially, it appears healthy: websites have grown more powerful and clever over the past decade. Unlike the sites of the 1990s, which mainly showed static text and images, sites in the 2000s could *do* things. We could manipulate a stick figure on a Google map and bring up photos taken at the real-world location. But beneath the surface, this "Web 2.0" era required a lot of tape and glue, because video and other multimedia elements often didn't work smoothly on basic Web pages.

To make everything come together, website developers needed help: they found it by turning away from HTML, the open programming standard that originally made the Web blossom. To get videos to play and animations to run, websites added proprietary programs to their sites—programs with futuristic-seeming names like Flash and Silverlight—and forced users to download a corresponding "plug-in" to run each one. That made websites complex and slow, which was annoying enough on a PC. But on mobile devices—the computing platform of the future—it was often unacceptable. After all, their screens are small and their connections apt to be uneven.

And that problem fueled a development that further undercut the Web: the rise of apps. These programs, customized for specific devices such as smart phones or tablet computers, deliver information, movies, and games from the Internet without making the user go to a page on the World Wide Web. Sure, there's talk about "open platforms" for apps; in contrast to the application store controlled by Apple, Google's Android Market lets any developer make an app available for devices that run the Android operating system. But this is a limited form of openness, far short of the founding ideal of the Web: that online information should be available to anyone with access to a browser and a search engine, which is to say everyone. Before the rise of the Web, it was possible to go online, but many people did it through closed services such as Prodigy, CompuServe, and America Online. Not until the Web emerged as a common platform, with its openness spelled out in the shared DNA of HTML, did the Internet turn into the world's greatest generator of economic value. But as time went on, the Web's status was jeopardized.

Fortunately, a handful of key people put aside the rivalries between them and led an insurrection in time to give the Web another chance.

Photo illustration by VAULT49

THE COUP

When Tim Berners-Lee concocted the idea of a giant web of interlinked documents in the late 1980s, he needed a way to tell the pages how to behave and how to link to each other. No computer languages at the time were quite up to the task, so he built his own. The result, HyperText Markup Language, was a set of labels to help structure documents so that a computer could interpret them, display them properly, and connect them to each other. Over time, HTML became the mother tongue of Berners-Lee's World Wide Web. By programming in HTML, Web developers tell a browser what to do when it encounters a page. The programmers essentially use a standardized dictionary to identify which parts of their pages are images, text, drop-down menus, and so on. Crucially, HTML itself embodies the ideal that knowledge is meant to be shared. Unlike proprietary software that hides its programming code, HTML lets anyone see and learn from its workings. Visit the *New York Times* website; click "view" in the menu of your Web browser, and then "source." Now you can see where Google gets its description of the site, because it's embedded in the HTML for nytimes.com:

```
<meta name="description" content="Find
breaking news, multimedia, reviews &amp;
opinion on Washington, business, sports,
movies, travel, books, jobs, education, real
estate, cars &amp; more">
```

But by the late 1990s, Berners-Lee was questioning whether HTML had outlived its purpose. The Internet boom was on, and HTML couldn't handle the complexity of what people and businesses were trying to use the Web for. He advocated starting over with a new set of instructions for the Web—one that made it more future-proof and, among other things, better able to handle the transfer of data between sites and users' computers. The World Wide Web Consortium (W3C), a standards body headed by Berners-Lee (and sheltered at MIT), decided to cease development of HTML.

Eventually what emerged was an alternative language known as XHTML. The Web industry at first supported the move, but it reconsidered that position as XHTML developed. It wasn't completely "backward compatible," which meant pages had to be redone to comply with the proposed new standard. And it was incredibly harsh in the way it handled mistakes made by Web programmers. Until then, the Web had been forgiving; it simply glossed over badly written code. The new system, however, mandated that any pages with malformed code return an error message. That seemed fine under lab conditions, but in practice even the most experienced Web designers had trouble writing perfectly formed XHTML code. Web pages were breaking without warning.

A splinter movement began to form, and the disagreement came to a head in 2004 during a W3C workshop at the headquarters of Adobe Systems, the maker of Flash, in San Jose, California. "The question was one of evolution or revolution," says Håkon Wium Lie, the chief technology officer for the browser maker Opera, who was one of the organizers of the event. "Should we evolve HTML as it was used on the Web, or try to create a new, cleaner language?"

A member of Wium Lie's team, a programmer named Ian Hickson, put it to a vote, proposing that the W3C and its industry partners bring back ordinary HTML. The measure was voted down, 11 to 8. But a number of the people who had backed Hickson's proposal had something in common: they represented Microsoft, Apple, and Mozilla, which actually made Web browsers. When it became clear that these rivals all agreed, their representatives knew they "had no choice but to do something," says Tantek Celik, who was Microsoft's W3C representative at the time and now works for Mozilla, maker of the Firefox browser.

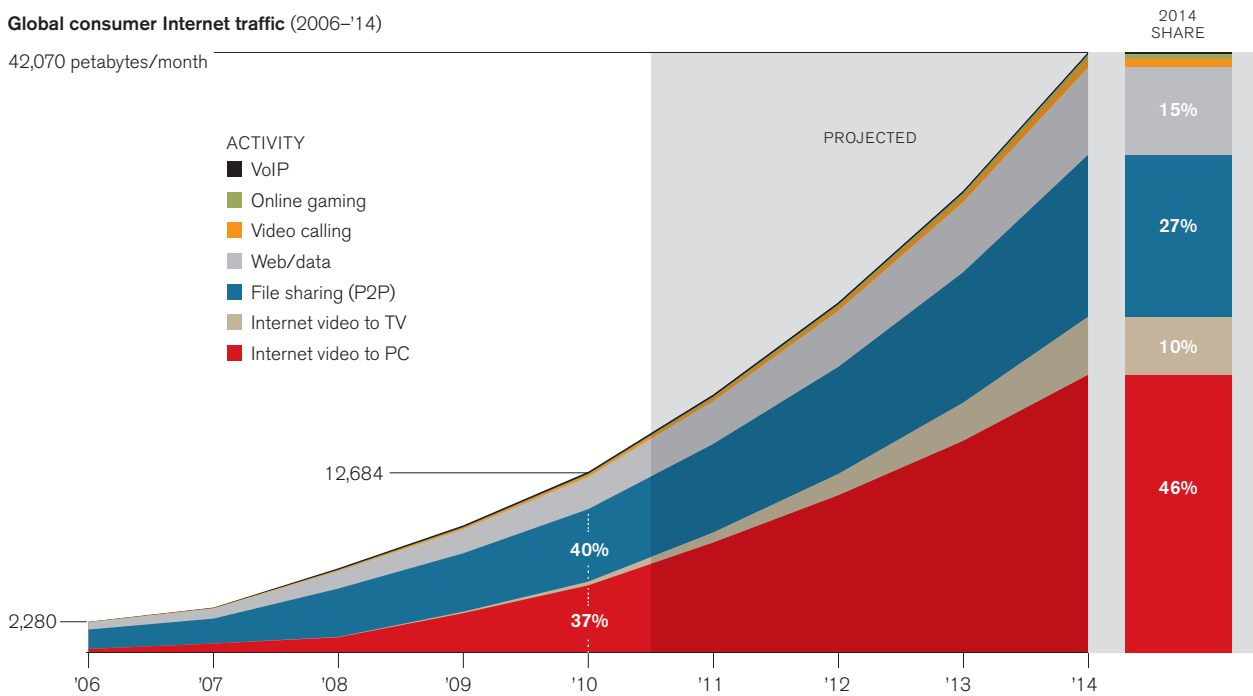
That something was, effectively, a coup. Two days after the meeting broke up, a faction led by Mozilla, Opera, and Apple announced that it was forming a new body to take up the work on HTML that was being abandoned by the W3C. The splinter group began drafting a new version of HTML almost immediately, and Hickson became its editor. Their update is known as HTML5, because it is essentially the fifth major version of the HTML dictionary.

> The technology will enshrine the best of the Web and create new possibilities. If a browser can store very large amounts of data, for example, you'll be able to do things on Web pages even when you're not connected to the Internet.

The W3C still toiled on a new version of XHTML, while most companies that make browsers doubled down on HTML (though Microsoft stepped back from involvement in both groups rather than put all its weight behind either standard). By the end of 2006, however, Berners-Lee was forced to essentially admit defeat. He said the W3C would collaborate with the rebels on HTML5 to create "one of the crown jewels of Web technology."

WATCH THIS

The introduction of a video element in HTML5 couldn't have come soon enough. According to projections from Cisco, online video viewing will soon surpass peer-to-peer file sharing as the activity responsible for the most traffic on the Internet.



Note: 1 petabyte = roughly 1,000,000 gigabytes. Source: Cisco Visual Networking Index

"The W3C lost sight of the fact that they have no power, and that's really all there is to it," says Hickson, who today works for Google. "Anyone can write a specification, but if nobody implements it, what is it but a particularly dry form of science fiction?" The W3C plans to officially ratify HTML5 sometime over the next two years. But that is merely a technical matter. The important point is that HTML5 has been developed by companies that actually have to answer to their customers. And their work has made for the biggest overhaul the programming of the Web has ever received.

NEW TRICKS

The central goal of HTML5 is to give websites the chance to expand beyond pages and into programs. For instance, the new terms in the HTML dictionary include "canvas," which lets a website designer insert a moving graphic that can be used in games or animations. The language will also have tags for video and audio, which should dramatically streamline the way the Web handles multimedia: it will be as easy for a Web developer to incorporate a film clip or a song as it is to place text and images.

While the Web is already saturated with music and video (YouTube alone might count for more than 10 percent of Internet traffic worldwide), HTML5 will clean this content up: multimedia elements will no longer require complex code and an add-on program such as Flash. This should make Web browsers faster and more efficient. Learning to build Web pages should become easier. And HTML5 could potentially boost security, by making it harder for attackers to dupe people into downloading malicious plug-in programs.

In some ways, HTML5 is taking the best of how the Web works and making it standard. For instance, today Gmail lets you take a file from a computer desktop and instantly attach it to an e-mail by dragging it into the browser window. Now that trick is being enshrined in HTML5, which means that easy dragging and dropping will become part of the common set of assumptions about what Web pages can do.

TOMMY McCALL

It's clear that the technology will open new possibilities, too. Still in development is a feature that enables a browser to store a large amount of data; the new specifications recommend that the amount be five megabytes per Web domain, or 1,000 times more than is currently possible. That capacity could enable people to use Web pages even when they're not connected to the Internet. You could use downtime on the subway to alter your fantasy-football lineup or write e-mails; then, when you had connectivity again, you'd find that the website "takes care of synching it up," says Anne van Kesteren, a software engineer who works on open standards for Opera.

Even when you're online, this feature should have benefits. If the browser itself can store information, it won't have to constantly retrieve what it needs from the website you're using. Everything should run faster when the pipes aren't clogged by constant chatter between your computer and a distant database. It also means a website can remember what you were creating or doing before you left to do something else. For example, Mozilla has been using this offline storage function in a still-experimental program that lets the browser act as photo-editing software. You'll be able to manipulate an image on a Web page and have your work saved there even before you've officially finished and uploaded the image.

Steve Jobs, who so detests what Flash does to the Web that he won't make iPads and iPhones capable of running it, praises the way HTML5 will enable websites to create advanced graphics and animations and richer typography.

Offline storage also promises to enhance a product sold by the Utah startup LucidChart, which lets people in different locations collaborate on documents over the Web—one user can watch in real time as another draws diagrams and moves images around on screen. When HTML5 becomes widespread, these users won't have to be working simultaneously. They could each make changes while offline, and the program would meld their changes later.

"It's finally possible for us to build applications on the Web that are not just imitations of desktop software," says LucidChart founder Ben Dilts. "It's now possible to build Web applications that are *better* than desktop software."

PHOTO BY CHRISTOPHER HARTING

What HTML5 Will Change

The new standard will make the Web run more smoothly and enable sites to offer new features. Here's a look at how one site might be refreshed thanks to the new programming.

STRUCTURE

New "tags" in the coding of sites will help them better organize the information they present to search engines' automated indexers. That could make search results more relevant for everyone.

VIDEO/AUDIO

Instead of requiring plug-ins to play video and audio, websites will let people load and show this content "natively" in their Web browsers. This should make for a simpler, faster, and more secure experience.

EDIT CONTENT

Users will be able to edit text in selected portions of a page. They might jot down notes about what they've viewed, and those notes will appear when they return to the site.

CANVAS

Animated graphics and other interactive content won't need a plug-in. A new "canvas" tag will let Web designers create graphical elements in HTML.

DRAG AND DROP

Dragging and dropping has been the standard way to move files around a computer desktop. Now HTML5 is bringing it to the Web. You could quickly upload a new photo of yourself to a social network.

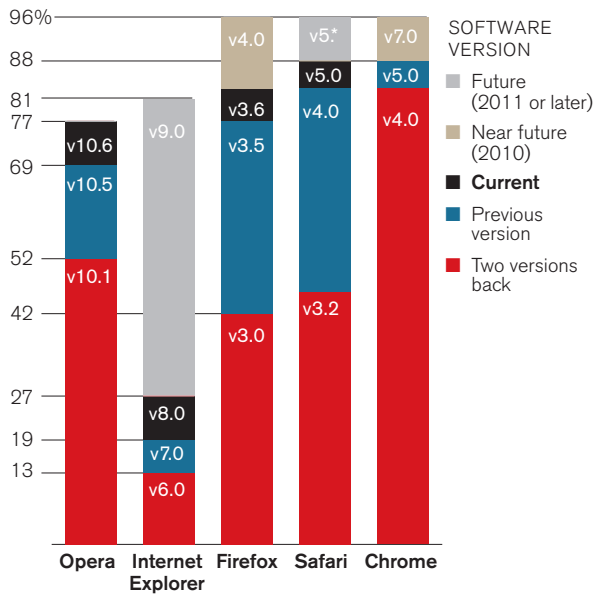
CHAT

An application programming interface associated with HTML5 will let Web developers set up a simple chat program. That could let their users interact with each other beyond the limits of a comments section.

WORK IN PROGRESS

Microsoft's Internet Explorer trails rival browsers in its ability to handle HTML5.

Percentage of new HTML5 features supported by major browsers



Source: caniuse.com

One of the most illustrative applications of HTML5 is "The Wilderness Downtown," an interactive video that the Canadian band Arcade Fire unveiled in September through a collaboration with Google. Type in the address of a house where you grew up, and the screen is soon given over to a video of a hooded man running down a dark, empty street to the accompaniment of a haunting, driving piece of music from the group's new album, *The Suburbs*. After a minute or so, the video changes, and the man seems to be sprinting through your old neighborhood, as depicted in satellite images and street-level pictures. The combination of sound and personalized images is engrossing and deeply affecting (the *New Yorker* called it "emotionally fraught"). And although some of the elements could have been created in a program like Flash, only HTML5 could have pulled together data, photos, and video so smoothly from multiple sources. The message behind the experiment: the next-generation Web will be more open to artistry.

Everyday sites will benefit, too. Apple CEO Steve Jobs, who so detests what Flash does to the Web that he won't make iPads and iPhones capable of running it, praises the way that HTML5 will enable websites to create advanced graphics and animations and richer typography. Its elegance has already improved the document-sharing website Scribd.com, one of the most prominent sites to begin using those elements of HTML5 that Web browsers can recognize today. Scribd's founders used to fret that the site, which used Flash to display documents, didn't look that great. The things people posted weren't as readable or as easy to manipulate as they should have been. They appeared in a frame, like "documents in a box," as Scribd cofounder Jared Friedman put it.

So Scribd's engineers spent six months rebuilding the site. They stopped using Flash to display documents, even though that meant they had to convert tens of millions of files to HTML5. Eventually their exhausting coding marathons paid off. After the renewal, Scribd's pages looked crisper because the documents had come out of their boxes. No longer did it seem as if users had to view the files through a lens. Readers began sticking around three times longer, Friedman says. "It was fantastic," he says. "Even we were surprised how good the metrics looked."

Scribd's renovation also made the site usable in the browser of an iPad, where it has the smoothness and light feel of an app. To turn a page, you can simply swipe a slider bar at the bottom of a document. This reflects what might ultimately be HTML5's most important benefit: the way it can make the Web useful on mobile devices.

Some of the credit for that achievement goes to Apple, which has, somewhat counterintuitively, become one of the biggest players on the Web, despite the fact that it has driven the app revolution and holds only a slim share of the browser market.

When Apple launched the iPhone in 2007, it dramatically altered the expectations the public had for the mobile Web. Until then, most smart phones offered only a substandard version of the Web as it appeared on PCs. Apple, however, opted to use the same system that underpinned its desktop Safari browser: WebKit, its open-source browser engine, the software component that translates the code of a Web page into what appears on the screen. In 2008, Google adopted WebKit as the basis of its Chrome browser, bringing it to desktops and Android phones. A string of phone makers followed: Nokia, Palm, Samsung, and the maker of the BlackBerry, Research in Motion, have incorporated WebKit browsers into their handsets. Today, WebKit is the dominant engine for mobile Web browsing—and because WebKit easily supports HTML5, Web developers can easily use it to create mobile versions of their sites that work well and look good on multiple devices.

NEW LIFE

HTML5 can't fix the Web overnight. There's still a long way to go. For example, while the browser makers are in agreement on most things, they continue to argue about which video standards

TOMMY McCALL

to support. It might also take some time for Web developers to put the technology to its most significant uses; first they'll want to be sure that enough people are using Web browsers that can fully handle HTML5 (*see "Work in Progress," p. 52*). That might not happen for a year or two. But eventually, more and more sites will follow Scribd's example. They will become sharper and more useful on PCs and phones and tablets alike. And before long, it might become less and less necessary for anyone to download dozens of individual apps. One program—the Web browser—could deliver a smooth, satisfying experience on either a PC or a mobile device.

This is not to say that apps will fade. In fact, they figure to be where the next generation of user-interface improvements will come from—before Web standards catch up again. And for some companies it still makes business sense to present content in a way that is customized for a certain platform. Giving people access to information more quickly and more simply than they could get it from a Web browser is a way to build customer loyalty, and making content exclusive to a certain device can be a way to get people to pay more for the material (or to pay for it at all). This is why *Wired* magazine proclaimed this summer that "the Web is dead."

But by cleaning it up and moving it forward, HTML5 provides good reason to believe that the Web will remain the main platform for new services, while apps remain secondary. And this matters because the health of the Web is vital for creativity and entrepreneurialism. One problem today is that the mess of the Web imposes a sort of tax on site creators, who often need to pay Adobe or Microsoft or someone else for the tools that make their multimedia plug-ins work. Yet they also need the Web, because its ubiquity offers unparalleled opportunities to reach an audience. That's the biggest reason the flourishing of this medium sparked an innovation boom in the 1990s. And it's why HTML5 will spur new investments in Web startups, says David Cowan, a partner at the venture capital firm Bessemer Venture Partners *(see Notebooks, p. 12)*.

"If you have two businesses—one of them that runs on the Web and one that runs in an app—the one that runs on the Web is going to be bigger, by definition," Cowan says. "There are lots of cute little app companies out there, but they're not going to be Amazon or eBay." tr

BOBBIE JOHNSON, A FORMER TECHNOLOGY CORRESPONDENT FOR THE *GUARDIAN*, IS A FREELANCE WRITER BASED IN BRIGHTON, ENGLAND.

Brain Control

Ed Boyden is learning how to alter behavior by using light to turn neurons on and off.

By DAVID H. FREEDMAN

The equipment in Ed Boyden's lab at MIT is nothing if not eclectic. There are machines for analyzing and assembling genes; a 3-D printer; a laser cutter capable of carving an object out of a block of metal; apparatus for cultivating and studying bacteria, plants, and fungi; a machine for preparing ultrathin slices of the brain; tools for analyzing electronic circuits; a series of high-resolution imaging devices. But what Boyden is most eager to show off is a small, ugly thing that looks like a hairy plastic tooth. It's actually the housing for about a dozen short optical fibers of different lengths, each fixed at one end to a light-emitting diode. When the tooth is implanted in, say, the brain of a mouse, each of those LEDs can deliver light to a different location. Using the device, Boyden can begin to control aspects of the mouse's behavior.

Mouse brains, or any other brains, wouldn't normally respond to embedded lights. But Boyden, who has appointments at MIT as eclectic as his lab equipment (assistant professor at the Media Lab, joint professor in the Department of Biological Engineering and the Department of Brain and Cognitive Sciences, and leader of the Synthetic Neurobiology Group), has modified certain brain cells with genes that make light-sensitive proteins in plants, fungi, and bacteria. Because the proteins cause the brains cells to fire when exposed to light, they give Boyden a way to turn the genetically engineered neurons on and off.

This neuronal trick has placed Boyden at the center of optogenetics, one of the newest fields in biology research—one he helped to invent, and one that could influence much of what happens in neuroscience in the coming decades. He seeks to answer a very basic question: how does the electrical activity of specific groups of neurons affect thoughts, feelings, and behavior? Obvious as that question may sound, it is one that has gone unanswered since brain cells were first observed over a century ago, for the simple reason that there has never been a precise way to know which neurons are doing what during a particular thought or behavior. Relatively new technologies like functional magnetic resonance imaging (fMRI) can show average activity levels among regions encompassing millions of neurons, and not-so-new technologies such as implanted electrodes can detect activity in a more specific area, but neither can trace the simultaneous or sequential firing of a particular set of neurons that may be strung through different regions of the brain. Yet these patterns of neural activity are the very essence of brain function, controlling cognition and behavior.

By using light to get specific sets of genetically modified neurons to fire, neuroscientists can observe how this activity is associated with specific stimuli and behaviors, as well as with brain disorders such as epilepsy and Parkinson's disease. Electrical engineers have developed principles by which various individual electronic circuits can be assembled into a fully functioning computer; similarly,

Photograph by DANA SMITH

SEEING LIGHTS
In his MIT lab, Ed Boyden studies how photosensitive proteins can be used to affect the workings of the brain.

Boyden hopes to uncover the principles by which individual groups of simultaneously firing neurons—brain circuits, as he likes to call them—work together to allow the brain to function.

Boyden's ultimate goal: to find ways to repair misfiring brains, much as electrical engineers analyze and alter electronic circuits when debugging computer hardware. "For the vast majority of treatments for human neurological problems, the mechanisms of the treatments aren't understood, which means there isn't really a logical way to continuously improve them," he says. "Our overarching goal is to figure out ways of controlling neural circuits so that we can avoid pathological states and engineer better treatments." And though he is well aware of the ethical issues that might surround a technology capable of precisely controlling certain aspects of human thought, mood, and behavior, he is confident that optogenetics—exactly because it *is* so precise—is far more likely to help than to hurt. "All drugs and other treatments for neurological disorders modulate thought and behavior in some way, and they all have side effects, some of them quite serious," he says. "The more we can target just those brain circuits involved in the pathology, and leave others alone, the fewer side effects we're likely to see. We may have to confront new risks at some point with this technology, but the precision of the technology by itself shouldn't be seen as a problem."

Being able to link specific groups of neurons to a behavioral change, whether the change is related to cognition, motor control, emotion, or sensory perception, is crucial to treating brain disorders.

Optogenetics is starting to have an enormous impact on neuroscience, says John Byrne, chairman of the neurobiology and anatomy department at the University of Texas Medical School at Houston. "We know a lot about how individual neurons function, and how regions of the brain process certain types of information, but the final frontier is learning how groups of neurons communicate in circuits to perform specific functions," he says. "That's what optogenetics is going to let us do with fantastic specificity."

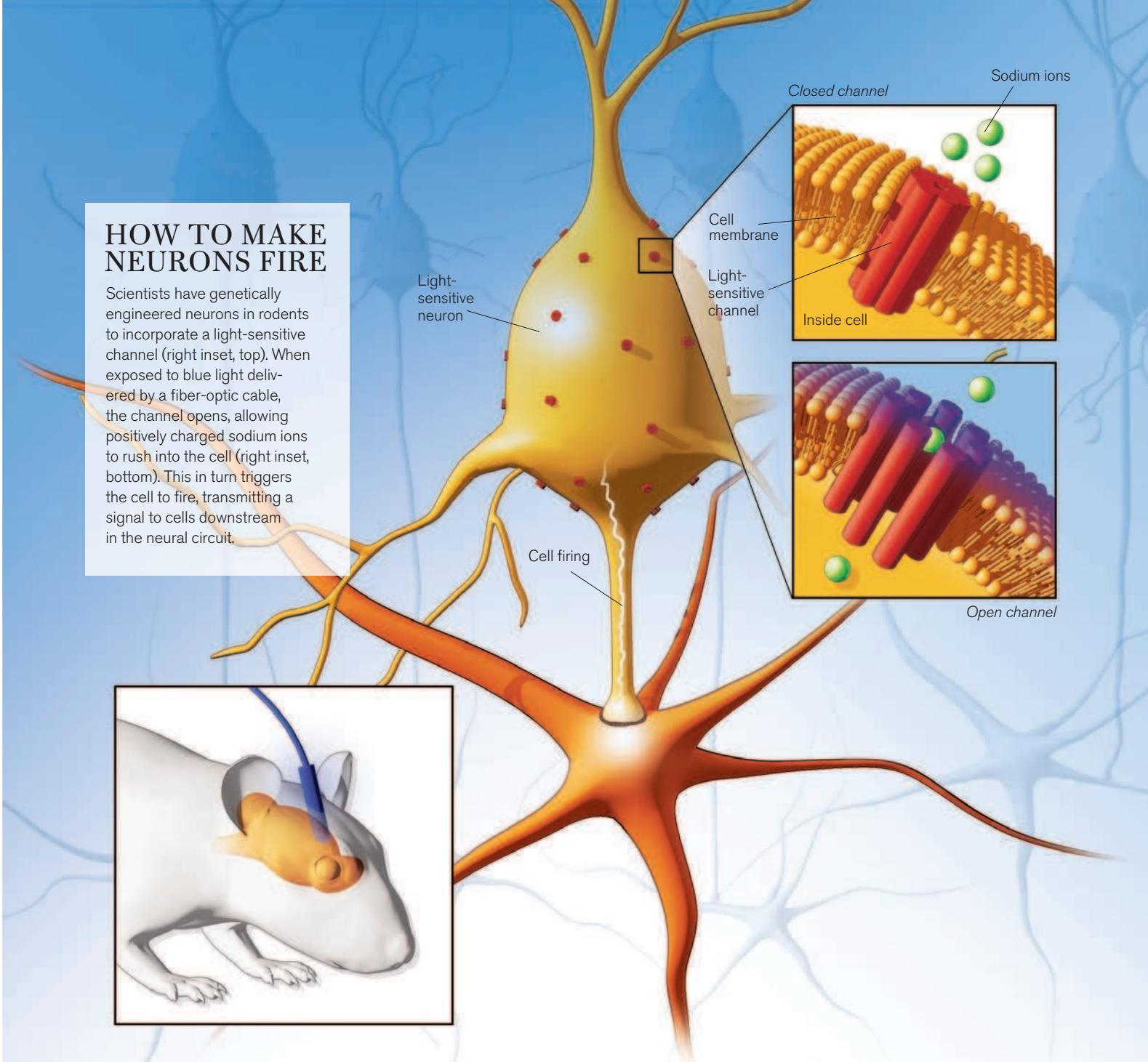
FIRE AWAY

When Boyden enrolled at MIT, at the age of 16, he quickly focused on exploring the principles of system control. Early on, he helped design a system that allowed a user to control a computer program through hand movements. But such problems felt a little too solvable—he was merely finding better ways to control systems that had already been proved controllable. The quantum-computing work getting under way in one corner of MIT's Media Lab seemed to pose the tougher kind of challenge that he sought, and Boyden spent his fourth year at the university trying to help develop a technique for taming the behavior of atoms that temporarily exist in multiple quantum-mechanical states. Unfortunately, the atoms proved too unruly to control, but that itself gave Boyden a new insight. "If the problem is impossible, you never get to the fun of controlling anything," he explains. "I needed to tackle a problem that was *nearly* impossible."

For Boyden, that was controlling the brain. After MIT, he earned a PhD in neuroscience at Stanford, where he collaborated with the neuroscientist Karl Deisseroth. Deisseroth's group, which wanted to isolate and analyze memory circuits, started working on a project that promised to provide a tool for exploring other brain circuits as well. Scientists had previously demonstrated ways that bursts of light could be used to coax brain cells into firing, but the techniques weren't refined enough to probe specific brain circuits. The Stanford researchers knew, however, that the cells of many plants and bacteria, as well as some of the cells in the eye, are photoreceptive: when light is shined on them, they generate a small voltage through the action of various forms of a protein collectively called opsins. Could opsins be used to make those methods more precise?

The answer, it turned out, was yes. Deisseroth, Boyden, and Boyden's fellow graduate student Feng Zhang chose microbial opsins that were especially efficient at converting light to electrical energy and pinpointed the genes that coded for those proteins. Then, in a technique that's standard in gene therapy, they used a virus to insert the opsin-producing genes into neurons. Once inside the neurons, the genes started producing opsins, with the result that the neurons fired when exposed to light. Boyden and his coworkers had found a precise, reliable way to stimulate specific groups of neurons and observe what happened when they fired.

Being able to link specific groups of neurons to a behavioral change, whether the change is related to cognition, motor control, emotion, or sensory perception, is crucial to treating brain disorders. If the specific neurons that are causing a problem can be identified, then researchers know where to aim potential therapies. But scientists aren't able to probe, monitor, and record the individual circuits that make up memories and thoughts, says Christian Wentz, a former graduate researcher in Boyden's MIT lab who has gone on to cofound Cerenova, an early-stage company in Cambridge, Massachusetts, that is developing optogenetic applications. "There's never been a way to establish connections between what happens on the cellular level in the brain and how we behave and think, and that's part of the reason why cognitive functions aren't well addressed by existing drugs or devices," he explains.



HOW TO MAKE NEURONS FIRE

Scientists have genetically engineered neurons in rodents to incorporate a light-sensitive channel (right inset, top). When exposed to blue light delivered by a fiber-optic cable, the channel opens, allowing positively charged sodium ions to rush into the cell (right inset, bottom). This in turn triggers the cell to fire, transmitting a signal to cells downstream in the neural circuit.

TAMI TOLPA

That's why it's been so difficult to understand and treat disorders of higher-order cognition and memory, such as Alzheimer's disease.

By allowing researchers to make specific groups of neurons fire on cue, Boyden's tooth-shaped bundle of optical fibers and LEDs provides a way to investigate those connections. After opsin-producing genes have been inserted into the neurons in a mouse so that the cells react to light, researchers implant Boyden's device into the part of the rodent's brain under study. Then they can control whether the neurons around the end of each optical fiber are firing. They target different sets of neurons in the mouse's brain and observe any behavioral changes that result when those neurons fire.

Boyden has been using this technique to experiment on mice that exhibit symptoms of anxiety, fear, memory loss, and even post-traumatic stress disorder (PTSD). As the optical-fiber device stimulates different groups of neurons, he looks for signs that the mouse's symptoms are getting better or worse. If the symptoms worsen when a particular group of neurons fire, then finding ways to prevent them from firing is a promising avenue for treatment; if the symptoms improve on stimulation, then it might be therapeutic to facilitate their firing.

Labs around the world have begun using the tools of optogenetics to study virtually every major brain-related disorder, including

Alzheimer's, Parkinson's, schizophrenia, epilepsy, sleep disorders, vision loss, and chronic pain. Consider epilepsy, which Jeffrey Noebels, a neuroscientist at Baylor College of Medicine in Houston, likens to some familiar computer problems. "We just don't know why the epileptic brain fails to sync properly at times, leading to a denial-of-service attack and a blue screen," he says. "We've been stymied in trying to learn more because we've had to interrogate the brain an entire region at a time, which is like trying to figure out what's wrong in a circuit board by blasting the entire board with an electric current. With optogenetics we can focus on the neurons that are playing a critical role, which is more like looking at the individual transistors." Treatment for severe epilepsy can involve surgically removing extensive chunks of the brain's cortex in order to prevent seizures, Noebels says, but that can lead to cognitive impairment and other problems. "If we can pick out the neurons that are the rabble-rousers, we might be able to sculpt the cortex into firing in a healthier way with drugs or stimulation," he says.

Boyden sees an even bigger role for optogenetics: not only can it help reveal the roles of individual brain circuits and potentially point to ways of fixing neural misfiring, he believes, but it can help researchers determine how all the different circuits fit together to create a fully functioning brain. How is a memory formed, lost, or altered? How does a thought trigger movement in a finger? How do we interpret visual images?

Many thousands of circuits will probably have to be matched to specific functions before the big picture emerges, and researchers will have to pick up their pace dramatically if they hope to match up most of them within a decade or two. To that end, Boyden envisions enlisting computers to automate the process. For example, a computer might investigate a circuit by sending light to a particular location in an animal's brain. To "read" what happens in response, it could look for glowing neurons or record how the animal moves or how its heart rate changes. Then it could quickly and repeatedly adjust the location of the light to try to maximize that response.

By thus probing brain circuits in mice, Boyden hopes to eventually "reverse-engineer" the neural networks that make up a brain, the way an electrical engineer might measure the *0*s and *1*s that are the outputs of an electronic chip to derive the software code programmed into the chip's circuitry. "The information in the brain is hard to understand if you don't know how it got computed," he says. "We want to uncover the original algorithm that is underlying function."

KEEPING QUIET

One of the most immediate and perhaps most important payoffs of Boyden's techniques is likely to be in drug development. "If we could use optical fibers to turn specific brain circuits on and off in an awake, behaving animal that has been given a drug, we could test which circuits are being affected by the drug and what the behavioral consequences are," says Boyden. "That would allow us to look for drugs that are more specific and effective to the right circuits, instead of just bathing the brain in a substance."

One surprising and important discovery that came out of Boyden's early studies involved a sort of "antistimulation" effect in brain circuits. Something odd happens when a group of neurons that tend to fire together is stimulated by light: while most of the cells fire more frequently, about a third actually fire less frequently. The effect has proved astonishingly consistent for all regions of the cortex, and for all types of behaviors and functions, in all animal species that have been tested. "The fact that a significant percentage of the neurons were completely inhibited told us there was an important principle of neuronal control to consider here," says Boyden. "If we want to make a brain circuit do something, we have to consider not just which neurons we excite but also which neurons we quiet downstream." That's likely to be especially important in developing new drugs. For example, a drug that aimed to relieve a symptom by stimulating one group of neurons could end up making things worse by indirectly silencing other neurons. On the other hand, silencing certain neurons could be beneficial—for example, if they had been causing epileptic seizures by firing uncontrollably.

Not only could optogenetic techniques reveal which neurons a treatment should aim to turn on or off, but they could become useful as treatments in themselves. For example, they could offer an improvement over the implantable devices that now deliver electrical jolts to treat Parkinson's and other disorders. Those devices tend to activate all the neurons near an implanted electrode, but an implanted fiber-optic device would activate only those neurons that had been altered with opsins—only the defective portions of a motor-control circuit or a mood-related circuit—while properly functioning neurons would be left alone. That, of course, would require using gene therapy on human patients, and such techniques, despite years of research, are still experimental. Eventually, however, if gene therapy proves safe, physicians could use optogenetics to repair faulty brains, perhaps by applying optical or electrical stimulation at precisely selected locations.

Will the public welcome implantable optical devices that could do such things, or will they fear that the techniques could be used to trigger or suppress particular thoughts, sensations, emotions, or behaviors? "People already have very different opinions about which psychiatric drugs are worth it and which ones aren't," Boyden says. "Those questions will be raised about this approach, too, and that's not a bad thing. There should always be an open dialogue between scientists, clinicians, regulatory agencies, and the public about the risks and benefits of new types of treatments." tr

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Giant Holes in the Ground

An expected nuclear renaissance has failed to materialize as plans for new plants are scrapped or delayed. What happened?

By MATTHEW L. WALD

PAY DIRT Construction has begun on a pair of large nuclear reactors at the Southern Company's Vogtle plant in Waynesboro, Georgia.

At the edge of the massive excavation project that is a preliminary step to building America's biggest nuclear power plant, Joshua Elkins stands next to two holes that span 42 acres in the red Georgia clay. Elkins maintains the earth-moving equipment that dug these holes, each as big as 15 football fields, 90 feet down to bedrock and then painstakingly refilled them to about 50 feet with soil tested to maintain stability in an earthquake. In helping to lay the foundation for the two 1,100-megawatt reactors the Southern Company is building here, his machines will contour the earth to specifications meticulously measured by GPS.

The last time anybody in the United States did excavation work for a new nuclear reactor, Elkins, who turned 27 in October, had not been born. Indeed, the groundbreaking for these Westinghouse-designed reactors at the Vogtle nuclear plant, 35 miles south of Augusta, Georgia, represents the first new nuclear construction since the 1970s. (Two existing reactors at the plant began commercial operation in 1987 and 1989.) An unlikely coalition of large utility companies, government policy makers, and environmentalists worried about global warming hoped that it and several other large planned plants in the United States would mark the beginning of a nuclear renaissance, with scores of new reactors being built around the country and worldwide.

And at first glance, circumstances finally seem to favor an expansion of nuclear power. Some $18.5 billion in federal loan guarantees was made available to cover as much as 80 percent of the cost of building a new plant, and the loan program may soon offer tens of billions more. (The new Vogtle reactors received $8.3 billion in loan guarantees from the U.S. Department of Energy in February.) President Obama, members of his administration, and the Republican leadership have all called for increased use of nuclear power as part of a long-term strategy for reducing U.S. reliance on fossil fuels. Also on the bandwagon for nuclear power are such influential technologists as Microsoft founder Bill Gates (*see Q&A, September/October 2010 and at technologyreview.com*) and longtime environmentalist Stewart Brand, who have argued that expanding nuclear capacity is essential to meeting growing worldwide electricity demand with zero-carbon energy sources.

But now the renaissance is stalled—both in the United States and in many other parts of the world. Apart from the Vogtle plant, the

Photographs by IMKE LASS

only U.S. nuclear project on which site work has started is across the Savannah River, near Jenkinsville, South Carolina, where the South Carolina Electric & Gas Company and the South Carolina Public Service Authority are planning to add two reactors to the existing V. C. Summer plant. Although many other utilities have applied for approval of reactor sites or projects in the last few months, most of the plans, including some of the most high-profile examples, have met obstacles. The Chicago-based utility Exelon, which is the nation's largest nuclear operator, with 17 units, has postponed its decision on whether to build a twin-unit nuclear plant in Victoria County, Texas. Two other large nuclear suppliers, NRG Energy and UniStar Nuclear Energy, have put off building long-planned plants in south Texas and Calvert County, Maryland, respectively.

The problems are not confined to the United States: projects are delayed in many nations with high hopes for nuclear power (*see "Nuclear Ambitions," p. 64*). The first of a new class of reactors designed by the French energy giant Areva is being built on Olkiluoto Island in Finland. It was begun in 2005 and was supposed to be in service by 2009; now the estimate is 2013. A second reactor using the Areva design, which is meant to be ultrareliable and features four redundant safety systems, is being built in Flamanville, France, but it seems to have run into similar problems; its target date has been pushed from 2012 to 2014. In Japan, construction schedules for two advanced boiling water reactors, a recent design from General Electric and Hitachi, have slipped by a year. China is constructing 24 reactors and plans to quadruple capacity by 2020, but it is currently a tiny player, producing only 2 percent of its electricity from nuclear power.

Today there are 104 operating nuclear reactors in the United States, supplying about 20 percent of electricity generated. Many have increased their capacity, by up to 20 percent, and most operate more than 90 percent of the time, which is slightly more than coal- or gas-fired power plants and much more than wind farms or solar plants. But all are aging. Jay Apt, the executive director of the Electricity Industry Center at Carnegie Mellon University, says that as old plants are retired and demand for electricity grows, the role of nuclear power could actually shrink. "I don't think it's a question of whether nuclear plants will be able to shoulder more of the burden," he says. "It's more a question of whether the nuclear plants will be able to continue shouldering the current share. Nuclear is going to have to run very fast to stay in place."

COST CONUNDRUM

Although the debate over nuclear power often focuses on thorny questions about its safety and its usefulness as a zero-carbon source of energy, the stumbling block to building more reactors in the United States has been, simply, cost. The price tag for the Vogtle reactors is expected to be between $12 billion and $14 billion, depending in part on what it costs the owners to borrow money for construction. The $14 billion estimate puts the price of the plant at about $6,000 per kilowatt (enough power to keep a window air conditioner running). That's far higher than the cost for other types of plants, whether they use renewable or fossil fuels. Building wind-turbine capacity costs roughly $2,000 to $2,500 per kilowatt; for gas-fired capacity, the figure is only $950 to $1,175. Advocates argue that despite the higher capital costs of a nuclear plant, those costs can be recovered to make nuclear power cheap over time: after all, a new plant is designed to run for 60 years, its operating and fuel costs are relatively low, and it can operate almost continuously, unlike plants that generate electricity from renewable sources. The problem is that the comparative costs of different fuels—and even the relative costs of building, say, a nuclear plant and a wind farm—can shift radically, throwing these calculations in doubt.

Whether billions of dollars for a new reactor is a smart investment depends on complex and unpredictable factors: the future cost of fossil fuels, for example, and the price, if any, placed on carbon emissions through government policy. In a 2008 analysis, the financial and asset management group Lazard looked at numerous energy technologies and, for each, estimated a "levelized cost of energy," which takes into account the expected lifetime of the generator, the estimated cost of the fuel, and the value of invested money over time. The analysis put the price of electricity generated

NUCLEAR ON THE HORIZON The two new reactors being built at the Vogtle plant represent the first groundbreaking on a nuclear plant in the United States since the 1970s; they will join a pair of existing reactors that have been operating since the late 1980s. Construction of Vogtle 3 and 4 will cost roughly $12 billion to $14 billion. The initial steps in the process involve digging holes for the foundation and refilling them within exacting specifications measured by GPS.

from nuclear power at $98 to $126 per megawatt-hour; for wind, the estimate was $44 to $91 per megawatt-hour, and for natural gas, it was $73 to $100 per megawatt-hour. The range in each set of numbers hints at the uncertainty. A more recent estimate by the Energy Information Administration, working from different assumptions, gave a more optimistic scenario for nuclear, putting its cost well below that of wind and other renewable sources and making it appear more competitive with fossil fuels (*see "Nuclear Ambitions," p. 64*). But Lazard's numbers also show that natural-gas-fired plants could produce electricity as cheaply as $59 per megawatt-hour, and coal plants as cheaply as $67 per megawatt-hour, if the prices of those fuels drop further. As it happens, prices of natural gas are currently low, and vast, accessible U.S. reserves have recently been found (*see "Natural Gas Changes the Energy Map," November/December 2009 and at technologyreview.com*).

So over time nuclear power may or may not produce electricity more cheaply than fossil fuels or renewable sources. For power companies, choosing to build a nuclear plant is thus an extremely risky decision, especially in tough financial times.

It is not coincidental that what signs of life the industry shows in the United States are mostly in the South, where so-called "cost-of-service" regulation guarantees some profit. When the plant is finished, accountants calculate the total amount the utility has invested in construction and equipment, minus depreciation. That "rate base," along with fuel, labor, and maintenance expenses, is used to figure the utility's cost of providing service; the rate customers pay is based on that cost plus an authorized rate of return on the capital investments. Thus most of the risk is borne by customers, not investors.

About half the United States uses a radically different pricing model, however. In Texas, for example, most electricity is sold in a daily auction. All generators get the same price for their electricity; that price is usually determined by the cost of natural gas used in the last few plants needed to generate the day's supply. Exelon says that the current low price of natural gas, around $4.50 per million British thermal units (BTUs), made building a new nuclear plant unthinkable. "We don't have the right stimulus now," says Christopher M. Crane, Exelon's president and chief operating officer. To make a new nuclear plant economically viable, he says, the price of natural gas would have to nearly double, to $8 per million BTUs, and a government cap-and-trade system would have to put a price on carbon dioxide emissions amounting to $25 a ton or more.

Carbon pricing alone could immediately make nuclear far more attractive. A typical power plant running on pulverized coal puts out just under two pounds of carbon dioxide per kilowatt-hour, so

NUCLEAR AMBITIONS

A number of countries have plans to expand nuclear power, despite the current slowdown.

TOP 10 NUCLEAR-POWER-GENERATING COUNTRIES

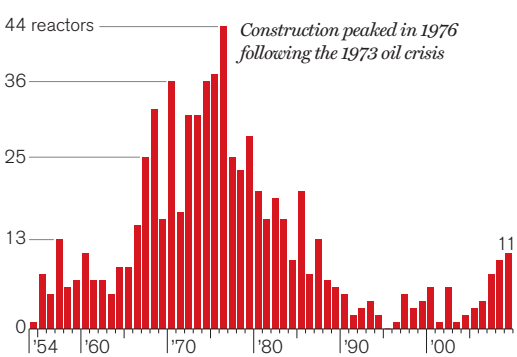
RANK/ COUNTRY	ELECTRIC POWER GENERATED, 2009 (Nuclear / All other sources (fossil and renewables)) Nuclear (billion kWh)	As a percentage of total electric gen.	REACTORS OPERABLE Number	REACTORS OPERABLE Total MW	REACTORS UNDER CONSTRUCTION Number	REACTORS UNDER CONSTRUCTION Total MW	REACTORS PLANNED Number	REACTORS PLANNED Total MW
1 **United States**	**798.7**	20.2%	**104**	101,216	**2**	2,234*	**9**	11,800
2 **France**	**391.7**	75.2	**58**	63,236	**1**	1,630	**1**	1,630
3 **Japan**	**263.1**	28.9	**55**	47,348	**2**	2,756	**12**	16,532
4 **Russia**	**152.8**	17.8	**32**	23,084	**10**	8,960	**14**	16,000
5 **South Korea**	**141.1**	34.8	**20**	17,716	**6**	6,700	**6**	8,190
6 **Germany**	**127.7**	26.1	**17**	20,339	**—**	—	**—**	—
7 **Canada**	**85.3**	14.8	**18**	12,679	**2**	1,500	**4**	4,400
8 **Ukraine**	**77.9**	48.6	**15**	13,168	**—**	—	**2**	1,900
9 **China**	**65.7**	1.9	**12**	9,624	**24**	26,550	**33**	37,450
10 **Spain**	**50.6**	17.5	**8**	7,448	**—**	—	**0**	0
World total	**2,560.0**	14	**440**	375,805	**59**	60,065	**149**	163,744

** Data for the U.S. is from the Energy Information Administration and was not included in World Nuclear Association totals as of August 2010.*
Sources: World Nuclear Association (reactor data); International Atomic Energy Agency (generation)

Nuclear proponents are heartened by the recent uptick in reactor construction starts . . .

GLOBAL NUCLEAR REACTOR CONSTRUCTION

(annually, 1954–2009)

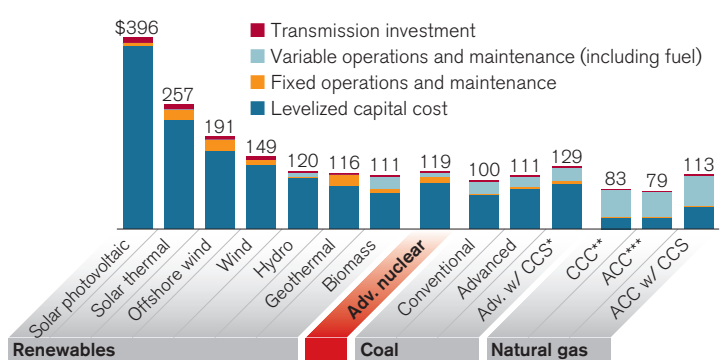


Source: International Atomic Energy Agency

But the cost of nuclear power must be right for the momentum to continue.

AVERAGE LEVELIZED COST TO GENERATE POWER

($ per megawatt-hour in the United States)



** Carbon capture and storage; **Conventional combined cycle; *** Advanced combined cycle.*
Source: U.S. Energy Information Administration

The International Energy Agency predicts that nuclear's share of global electricity production will decline in the coming decades under a "business as usual" scenario. But nuclear would play an important role in a plan it calls the "Blue Map" scenario, which would cut carbon emissions in half by 2050.

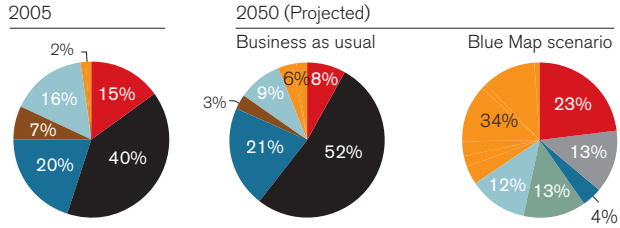
GLOBAL ELECTRIC PRODUCTION

GENERATING TECHNOLOGY

Nuclear

Fossil Fuels
- Coal
- Coal + CCS
- Gas
- Gas + CCS
- Oil

Renewables
- Hydro
- All others*



**Includes wind, bio, geothermal, tidal, hydrogen, and solar. Source: International Energy Agency*

TOMMY McCALL

a carbon tax or a market price of $10 per ton of carbon pollution would cost that plant about a penny per kilowatt-hour—which is a lot considering that the average kilowatt-hour sells for about 10 cents. A 1,100-megawatt reactor operating 90 percent of the hours in a year would gain a cost advantage of about $87 million a year per $10 of carbon price, and some industry analysts project prices of $60 or $80 a ton, meaning a cost advantage of hundreds of millions of dollars a year. But all this is still only theoretical, says Carnegie Mellon's Apt. "We don't have a climate bill, and right now there's a lot of uncertainty whether we ever will," he points out.

Nevertheless, some observers believe that if we want to achieve low-carbon energy, and replace gasoline- and diesel-powered vehicles with electric cars, we will eventually and inevitably need nuclear power. The nuclear industry "has certainly been hit by the financial meltdown and the worldwide recession," says Brian D. Wirth, a professor of computational nuclear engineering at the University of Tennessee. But he predicts that the demand for electricity, and the price of natural gas, will snap back in three to five years, creating a new opening for nuclear.

INVENTING SMALLER

Since much of the high cost—and financial risk—of nuclear power is tied to the expense of building large plants, one obvious prescription is for smaller reactors and modular designs. Though they would show higher costs per kilowatt of capacity, smaller plants could represent far less financial risk, and far more flexibility for utilities that must adapt to shifting electricity demands.

Some designs are already moving toward production. NuScale Power, a company in Corvallis, Oregon, has developed a plan for a modular unit that measures 60 feet by 14 feet and weights 300 tons—small enough to be moved by rail or barge. An installation might consist of one unit or up to 24, each generating a mere 45 megawatts. The company says that in case of accident or unexpected shutdown, the heat is carried away by natural circulation, so no emergency pumps and valves are required—and that in a worst-case scenario, no individual unit could release enough radiation to necessitate a plan for evacuating the surrounding area.

Babcock & Wilcox, a giant construction and engineering firm based in Charlotte, North Carolina, has another modular design, for a 125-megawatt reactor. It would be built in a factory and shipped to an underground silo, reducing the risk of successful terrorist attack. The reactor would run four years without requiring refueling, which is about double the longest cycle that is now common.

These plans represent something the industry has not seen in decades: private-sector engineers who think they can make money by being entrepreneurial with new reactor designs. Per F. Peterson, a professor of nuclear engineering at the University of California, Berkeley, says he has high hopes for the smaller reactors, partly because each one represents less risk for investors willing to take a chance on something new. "The first-mover barriers and difficulties are so much smaller for the small modular reactor," he says.

DECAYING PROSPECTS

At the Vogtle site, in a sprawling array of temporary office trailers, David Jones is overseeing construction of the new reactors. A 30-year veteran at the Southern Company who previously served as vice president of engineering for its six existing reactors, Jones started his career in the nuclear industry in the mid-1970s, using a tape measure to make sure that the steel reinforcing bars in the main auxiliary building at the Tennessee Valley Authority's Bellefonte 1 plant were the right thickness and distance apart. His dream was to help the TVA build nuclear plants up and down the Tennessee River. But construction on Bellefonte was stopped in the late 1980s. The TVA had underestimated its costs and overestimated both the demand for electricity and its ability to manage nuclear projects.

These days, Jones is quite conscious that the parade of planned nuclear projects behind him has disappeared. But, he says, "someone has to be first, and we are first." If the Southern Company can "prove that [nuclear] is a viable option" by finishing the job on schedule and on budget, he maintains, others will follow.

Not everyone is so sure. Richard Lester, chairman of the nuclear science and engineering department at MIT, says it is uncertain whether success at the Georgia site and other planned nuclear plants would be enough to encourage a nuclear resurgence in this country. He points out that these early plants will have extensive government help that is unlikely to be available to would-be successors. "The question is whether one can see a path from those first few built under pretty exceptional circumstances—probably not sustainable circumstances when it comes to government support," he says. "If one takes the larger view, what really counts here is whether we can get up to 300 or 400 [plants]." He adds, "Even if one could get three or four or five new nuclear plants built in the U.S., the question was always going to be: well, what then? That question is still very much on the table."

Severin Borenstein, codirector of the Energy Institute at the Haas School of Business at the University of California, Berkeley, blames the standstill on a failure to pass legislation to address the threat of climate change.

"It's hard to be very optimistic about it at this point," Borenstein says of the outlook for the nuclear industry. "The original impetus behind the nuclear renaissance was [that nuclear energy would be] low-cost and low-carbon. It's not turning out to be nearly as low-cost as the proponents claimed, and the electorate is not turning out to care that much about low-carbon. This idea that the age of coal is over is not true." tr

MATTHEW L. WALD IS A REPORTER AT THE *NEW YORK TIMES*. HE FREQUENTLY COVERS THE NUCLEAR INDUSTRY.

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BRIEFING
Mobile Communications

MANUEL RIBERIO / ALAMY

Can Mobile Operators Afford to Keep Up with the Demand for Bandwidth?

Even in the face of a global economic meltdown, wireless technology has been an unqualified success. Energy-efficient microprocessors power mobile devices that let people share words, sounds, and images—and tap into a world of entertainment—almost anywhere. But the success of these smart phones, e-readers, and tablets challenges the telecommunications companies that must provide connectivity for a device long after the store receipt for it has been lost.

These businesses are now spending billions of dollars upgrading infrastructure to handle the traffic, buying new radio spectrum licenses, and deploying next-generation broadband technologies, such as WiMax and LTE *(see "Feeding the Bandwidth Beast," p. 69)*, that make better use of the portions of the spectrum the companies already own.

Wireless operators hope this will satisfy the appetite of data-hungry subscribers. However, experience suggests that unless constraints are imposed, that appetite will simply expand to consume the new bandwidth, leaving operators right back where they started *(see "Making Wireless like Wired," p. 70)*. In the United States, this problem has already forced AT&T, which is the national carrier for the iPhone, to stop offering unlimited data plans to new subscribers. Some think the only way to guarantee that data hogs won't crowd out, say, someone simply trying to make a phone call will be to introduce pricing based on the type of traffic, so that those wanting to stream high-quality video would pay a premium. Such a practice might not be allowed, however, if government regulations enshrine the principle of network neutrality in wireless systems *(see "Should the Airwaves Be Neutral?" p. 73)*, and it's likely that the shape of mobile networks in this decade will owe as much to deals done in national legislatures as to any technical innovation. *—Stephen Cass*

Even in developing countries, such as India, cellular phones are ubiquitous.

RAJESH KUMAR SINGH/AP

MARKET WATCH

Going from Calls to Connections

At first glance, the global cell-phone industry appears to be experiencing a golden age. Worldwide sales of mobile devices grew 15 percent in the first half of this year compared with the same period last year, thanks in part to a flood of new smart phones, according to the technology research firm Gartner. In the United States, mobile-phone carriers' revenue hit a record $152 billion in 2009, nearly quadrupling what it was a decade ago. And yet the industry's future is uncertain.

The long boom in mobile communications has been fueled almost entirely by more people making more phone calls. In 1999 the average American subscriber spent just under three minutes a day chatting on a cell phone. By 2009, average daily usage had jumped to nearly 22 minutes. Even today, in a world of Web-friendly cell phones, Netflix-enabled iPads, and 3G-compatible laptop computers, simple phone calls still produce more than three-quarters of the industry's revenue in the United States.

But after three decades of growth, new demand for voice service is hard to come by in the industrialized world. More than eight out of 10 people in the United States, Japan, and Europe now own a mobile phone, and their voice usage seems to be leveling off. The average AT&T customer chatted for 22 minutes per day in the third quarter, down slightly from 23 minutes a day in 2009. Companies like Britain's Vodafone, which has networks throughout the Middle East and Africa, still have a chance to reach largely untapped populations—but their potential new customers tend to have much less money to spend than the old ones.

DATA POINT

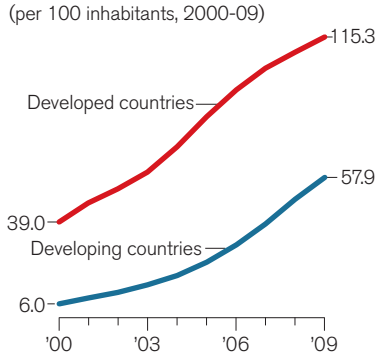
56.6%

The portion of the geographic U.S. with mobile broadband coverage. This area is home to 98.1 percent of the population.

CATCHING UP

There's still plenty of room for cell-phone growth outside the developed world.

Cellular subscriptions
(per 100 inhabitants, 2000-09)



Sources: ITU World Telecommunication/ICT Indicators database

Faced with stagnation in their largest voice markets, carriers are racing to roll out data-friendly networks that can support new applications *(see "Feeding the Bandwidth Beast," p. 69)*, including video on demand and services that let people use their cell phones to connect their laptops to the Internet. The carriers' rush to develop new data services promises to be a boon for equipment makers such as Alcatel-Lucent and Motorola. The next-generation gear these companies are selling should roughly triple wireless capacity, easing congestion in airwaves now overwhelmed by iPhones, Droids, and BlackBerrys.

The shift toward data is what drove this year's decision by the cellular industry's main trade group, CTIA, to change the terminology in its semiannual survey so that it now tallies wireless "connections" (i.e., devices) rather than wireless subscribers (i.e., people). The change has had the happy effect of diverting attention from the slowdown in traditional-subscriber growth, since a mobile-phone subscription and a subscription for a laptop's high-speed Internet card count the same in the survey. Whether selling those new wireless connections proves as lucrative as selling phone calls remains to be seen. *—Scott Woolley*

TECHNOLOGY OVERVIEW

Feeding the Bandwidth Beast

Trying to meet the skyrocketing demand fueled by smart phones and other mobile devices, wireless service providers are striving to introduce new infrastructure while bolstering existing networks.

The new networks being rolled out come in two flavors: WiMax and Long Term Evolution (LTE). The two use similar tricks to allow significant bandwidth increases over the data links used today.

One trick is called orthogonal frequency-division multiplexing (OFDM), which allows a base station to split a chunk of radio spectrum into subchannels. The signal strength of the subchannels and the number of channels assigned to different devices can be varied as needed. OFDM allows high data rates, even far from a base station, and it copes well with the type of radio interference that is common in urban areas, where signals reflect off walls to produce confusing echoes. Both LTE and WiMax also support a technique known as multiple input, multiple output (MIMO), which uses several antennas to create a single wireless connection. MIMO can pack data more densely into the available wireless spectrum than a single-antenna system that uses the same amount of power.

WiMax came to market two years ahead of LTE and offers a theoretical maximum download speed of 144 megabits per second, compared with LTE's 360 (a typical wired residential broadband connection in the United States runs at around 10 megabits per second). LTE may seem to have a crushing speed advantage, but in practice operators are far from reaching the boundaries of either technology. In the United States, Sprint's WiMax network offers speeds of three to six megabits per second, while Verizon's LTE network, which is scheduled to launch before the end of 2010, will offer five to 12 megabits per second. Although Sprint and Verizon are branding these services as 4G, they don't actually meet the performance criteria that the International Telecommunication Union says officially define a 4G service. But newer versions of both WiMax and LTE are in development that could meet those standards, providing downloads at 1,000 megabits per second or faster.

Although WiMax developed faster (the first large-scale deployments occurred in 2008), most carriers in the United States,

New cellular modems will provide broadband Internet connections with speeds that can rival those of some wired networks.

SAMSUNG

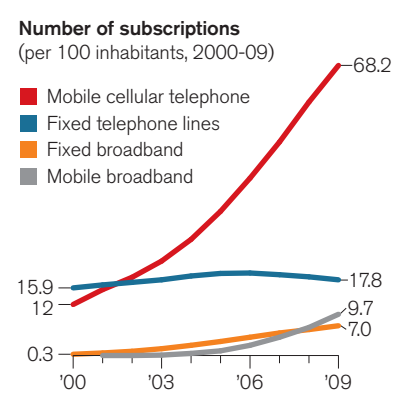
DATA POINT

277 million

The number of Chinese accessing the Internet through mobile devices last June, up 43 million since December 2009.

MOBILE MIGRATION

Wireless technologies are outpacing their wired equivalents.



Sources: ITU World Telecommunication/ICT Indicators database

Europe, and Japan are using LTE for their next-generation networks. A major reason is that carriers believe LTE will be more technically straightforward to integrate with their established infrastructure.

But some providers, such as T-Mobile in the United States, are avoiding both WiMax and LTE, instead upgrading their existing 3G networks to an improved system called HSPA+. T-Mobile says HSPA+ allows peak download speeds of 21 megabits per second—enough to compete with next-generation networks, at least for now.

In fact, all network operators are trying to boost the capacity and resilience of their 3G data networks as demand soars. Over the next four years, as next-generation systems are built and 3G chips become cheap enough to appear in a wide range of consumer devices, those systems will attract more new subscribers than LTE.

The biggest issue in improving any of these systems is wired networking, not wireless. Cell towers and base stations must be connected to network hubs themselves. These "backhaul" links, traditionally employing copper phone wires or specialized microwave connections, have become bottlenecks in recent years, prompting carriers to shift to more expensive optical-fiber connections. Some 95 percent of the backhaul for Verizon's LTE network will be fiber when it launches this year. But digging up streets and laying fiber in densely populated places can be expensive and slow. That's held up AT&T's efforts to improve its 3G service in New York, which is laboring under the load of thousands of iPhone users. *—Tom Simonite*

DATA POINT

90%

Portion of the world's population reached by a cell-phone signal. In 2003, only 61 percent of the global population had coverage.

Video services, such as Netflix, are helping drive demand for more bandwidth.

NETFLIX

INDUSTRY CHALLENGES

Making Wireless like Wired

Users are being lured to new mobile technologies with the promise of being able to do wirelessly all that they can do on a wired connection. But as bandwidth demand soars for applications such as streaming video, the wireless industry is having trouble delivering.

When a wired network becomes congested, the phone or cable company can add more physical connections. But wireless providers can't do the equivalent—allocate another radio channel to a network—because they are licensed to use fixed portions of the radio spectrum.

While the next-generation networks being built today *(see "Feeding the Bandwidth Beast," p. 69)* will allow much more data to be transmitted over a given chunk of the spectrum, it is unlikely that they can keep pace with demand, which is growing at 55 percent annually in North America, according to ABI Research. When people get access to more bandwidth, their appetite grows commensurately. For example, users of Sprint's first WiMax-capable phone, the EVO 4G, typically increase their data usage by a factor of three to three and a half.

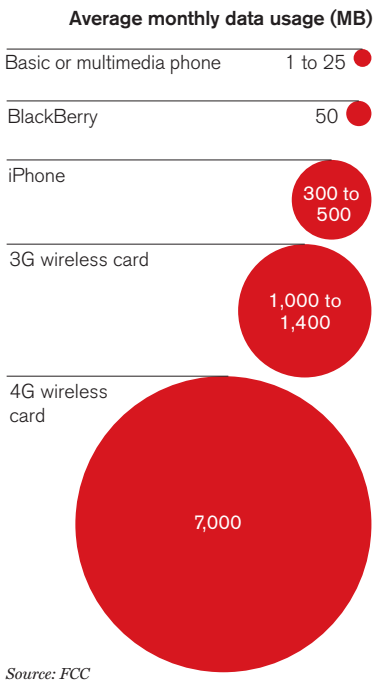
An even bigger strain on the network will come from broadband modems used by larger devices like laptop, tablet, and even desktop computers. The research firm Infonetics predicts that by 2013, more North Americans will be connecting to the Internet with mobile broadband than with any other technology.

Wary of suffering a version of AT&T's "iPhone problem" (users of the Apple device overwhelmed the network, leading to dropped calls), carriers are investing in techniques to predict and dissipate data congestion. Sophisticated models of what happens when, say, fans at a ball game all try to access the Major League Baseball website can be used to stress-test network infrastructure. Companies that sell hardware and software to manage heavy wireless traffic report growing interest from worried carriers.

Options include hardware that can switch data streams from an overloaded connection to less busy circuits or even gently slow video downloads to prevent calls from dropping during a usage spike.

INCREASING APPETITE

The capabilities of new devices inspire users to download more and more data.



Source: FCC

Many in the industry believe that these same techniques will eventually have to be used to reduce demand by bandwidth-hogging applications. Rather than preserving the flat-price model of wired connections, companies may charge customers different amounts for service, depending on the kinds of applications they access—more for streaming HD movies, less for making ordinary calls. That could run counter to "net neutrality" legislation that would require networks to treat all data packets the same; the desire to preserve the possibility of a multitiered plan was one of the motivations for Verizon's recent and controversial "pact" with Google advocating different regulations for wired and wireless connections *(see "Should the Airwaves Be Neutral?" p. 73, and Q&A, p. 36)*. For users, this pricing difference may ultimately become the biggest practical distinction between wired and wireless. *—Tom Simonite*

OVER THE HORIZON

Tuning the Internet for Mobility

The Internet is becoming the de facto standard for all telecommunications; services like voice-over-IP and Internet Protocol television are overtaking the technologies purpose-built for telephones and televisions. But the protocols underlying the Internet make assumptions about physical connections that do not always fit well with wireless communications: that all links are generally the same and provide close to real-time connectivity from one end of the link to the other. Wireless services are often intermittent, vary widely in the amount of bandwidth they offer, and, especially in the case of satellite services, can lag, making websites sluggish to respond to clicks. As new applications place new demands on Internet-based networks, "maybe it makes more sense to think about some radically different architectures," says Preston Marshall, director of the wireless-networking division at the University of Southern California's Information Sciences Institute and a former manager for many of the advanced wireless technology programs at the Defense Advanced Research Projects Agency (DARPA).

This kind of thinking informs efforts to integrate technologies such as delay-tolerant networking (DTN) with Internet protocols. Because DTN allows communication even when establishing an end-to-end link is impossible, it would make networks more robust. It's also well suited for applications such as machine-to-machine communication. For example, a meter on a "smart" electric grid may need to exchange only small amounts of data with the power company within a relatively broad window of time; it doesn't need a high-bandwidth real-time connection.

NASA is testing delay-tolerant networking to allow researchers to monitor experiments onboard the International Space Station.

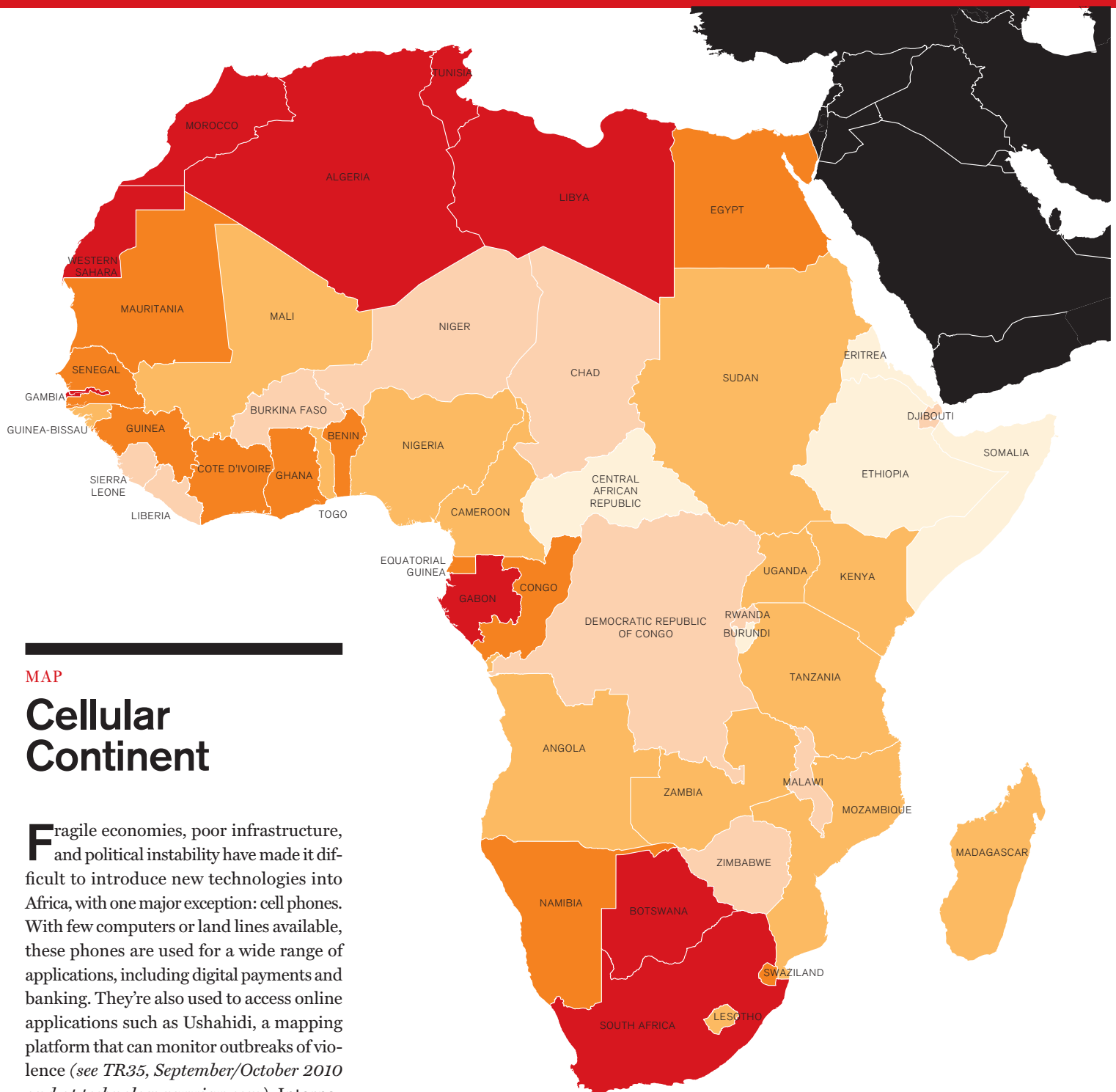
Beyond DTN, it may ultimately be possible to shift between different kinds of wireless links from moment to moment, depending on the type of data to be accessed. A user could browse for a movie title using a low-lag but low-bandwidth cellular connection and then download the movie over a high-lag, high-bandwidth satellite connection. *—Stephen Cass*

DATA POINT

122 million

The number of Wi-Fi base stations in Europe recorded by Skyhook, which maintains a database on base stations for geolocation purposes. In the United States and Canada, 81 million base stations have been recorded.

NASA



MAP

Cellular Continent

Fragile economies, poor infrastructure, and political instability have made it difficult to introduce new technologies into Africa, with one major exception: cell phones. With few computers or land lines available, these phones are used for a wide range of applications, including digital payments and banking. They're also used to access online applications such as Ushahidi, a mapping platform that can monitor outbreaks of violence *(see TR35, September/October 2010 and at technologyrewview.com)*. International telecommunications companies such as Vodafone are trying to expand rapidly throughout Africa, because it's one of the last places in the world with a large supply of potential customers who don't already own a cell phone *(see "Going from Calls to Connections," p. 68)*. *—Stephen Cass*

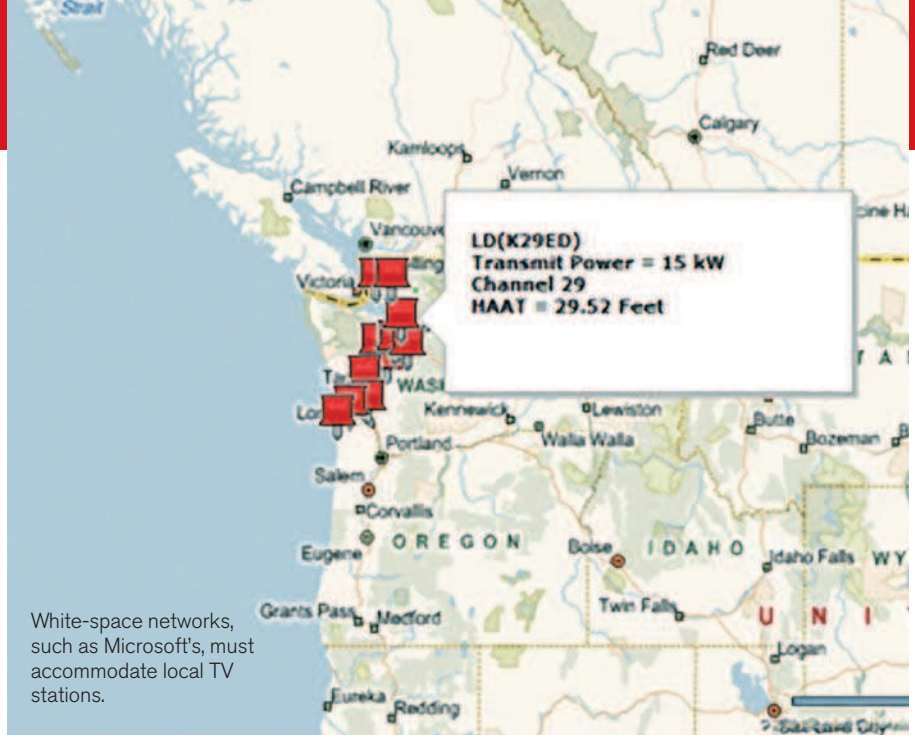
Source: ITU World Telecommunications/ICT indicators database

POLICY

Should the Airwaves Be Neutral?

The utility of a user's next smart phone—what it will be capable of doing, and what it will be allowed to do—could be determined not by technology companies or phone company executives but, rather, by legislatures and government agencies. Around the world, these bodies are wrangling over whether to require that the airwaves be run as neutral networks, meaning that providers would have to let people use cell-phone bandwidth however they choose *(see "Making Wireless like Wired," p. 70, and Q&A, p. 36).*

In the United States, the debate heated up in April, when a federal appeals court ruled that the Federal Communications Commission lacked the power to impose network neutrality by regulatory fiat, even for the wired Internet. Momentum for wireless net neutrality slowed further this summer when one of its staunchest proponents, Google, effectively switched sides. In 2008 the search giant risked $4.6 billion by guaranteeing a minimum bid for an FCC spectrum auction, on the condition that any winner provide open access for third-party devices and applications (Verizon subsequently bought nearly all the auctioned spectrum). But this August, Google decided that such rules shouldn't apply to all wireless networks—that when capacity is tight, simply letting users communicate however they like risks a huge traffic jam that benefits no one. Despite efforts by the FCC to find a way around the April appeals court decision, it now seems likely that any far-reaching rules will take an act of Congress. That is unlikely, since many Republican legislators fiercely oppose net neutrality. *—Scott Woolley*



White-space networks, such as Microsoft's, must accommodate local TV stations.

MICROSOFT

RESEARCH TO WATCH

New Spectrum from Old

The global switch from analog to digital television has created an unusual opportunity, opening up portions of the radio spectrum around the world that have been off limits to anyone but broadcasters for decades. These newly vacant "white spaces" can be found from 52 to 806 megahertz, and telecommunications companies hope to be able to use some of them for long-range broadband wireless connections. In the United States, the Federal Communications Commission announced rules for unlicensed use of white spaces in September, but a number of pilot systems have already been deployed. The first such public network, introduced in rural Virginia by Spectrum Bridge in October of last year, used white-space frequencies to connect Wi-Fi hot spots to the Internet.

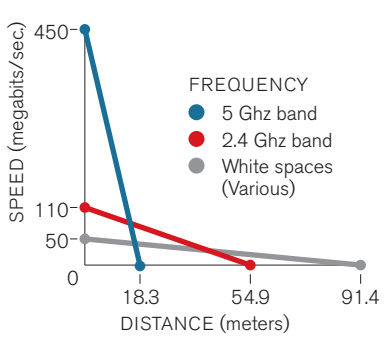
One significant difficulty in opening up white spaces to mainstream consumer use is that the exact frequencies available vary from place to place, largely depending on the bands used by local TV stations.

Consequently, researchers are focusing on making wireless equipment smart enough to figure out which frequencies it should be using. At Microsoft Research, Ranveer Chandra *(see TR35, September/October 2010 and at technologyreview.com)* has developed a prototype system in which base stations determine their location using GPS and then check the Web to find out which radio bands are allocated to local broadcasters. *—Stephen Cass*

THE TRADE-OFF

For a given amount of radio power, frequencies in the part of the spectrum where white spaces are found carry less data, but they can carry it much farther.

Wi-Fi data speeds vs. distance



Sources: Perspective, part of the Ingenious Consulting Group

THE BIG PICTURE

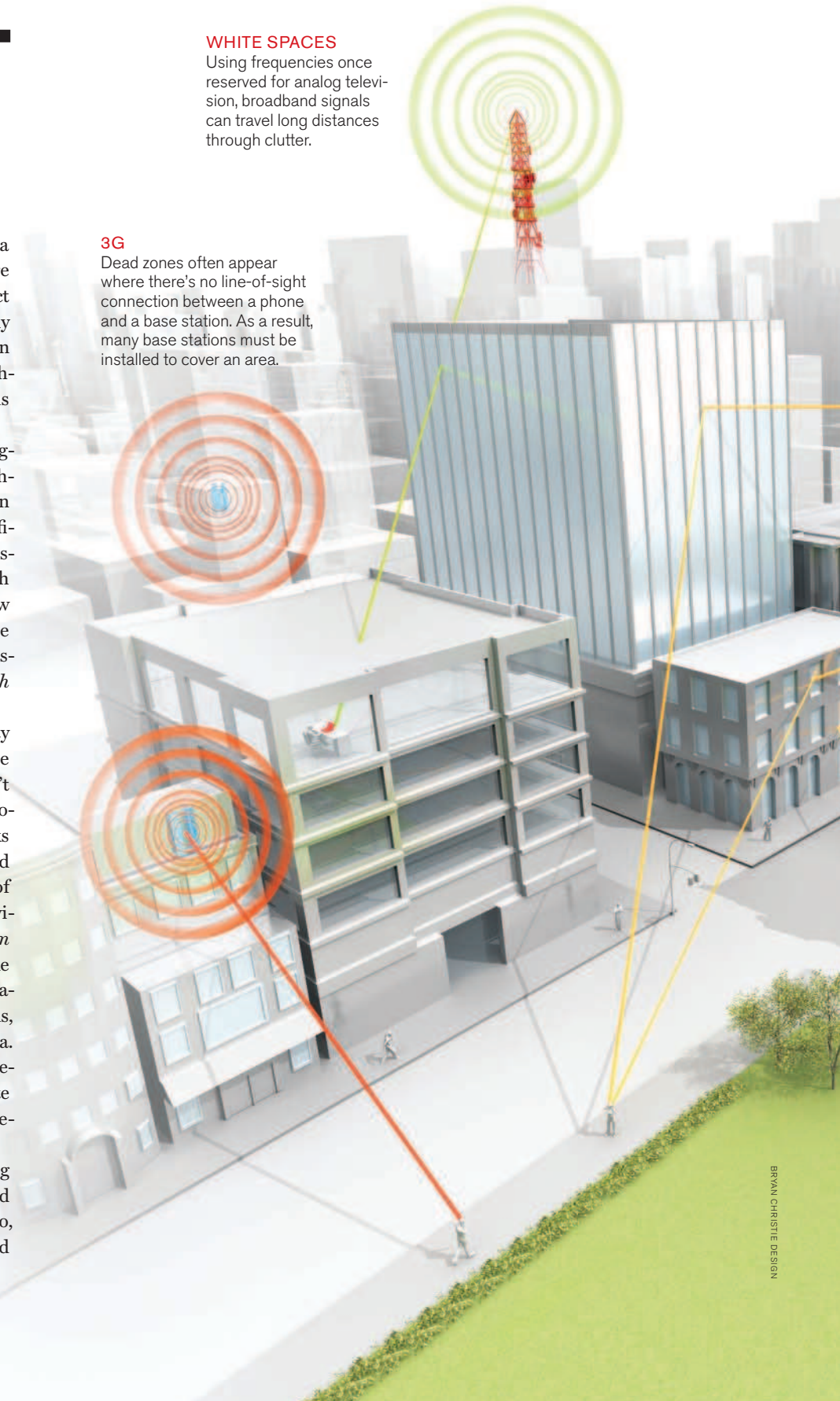
Radio City

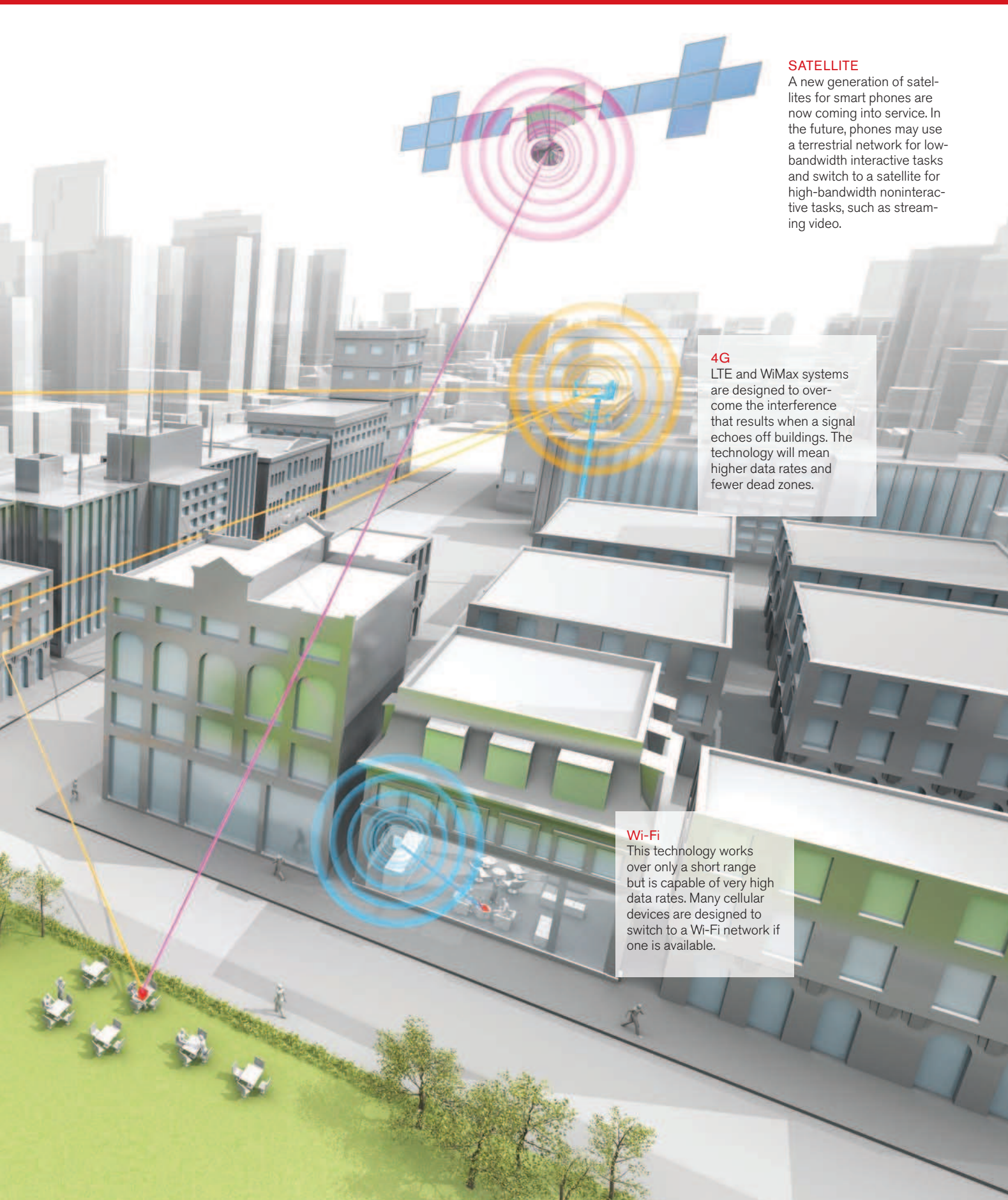
THERE ARE a lot of ways to get your data fix while out and about, and even more are on the way. Because radio waves interact with the physical environment to a vastly greater degree than signals isolated within a copper or fiber-optic cable, which technology works best for you often depends on where you are.

In cities, buildings block and reflect signals, creating dead zones and bandwidth-sapping interference. High population density can make capacity demands difficult to manage, especially in business districts that on weekdays are flooded with smart-phone-wielding commuters. New 4G technologies should be able to handle reflection better and carry more data, easing congestion *(see "Feeding the Bandwidth Beast," p. 69)*.

In rural areas, low population density means that people are often outside the range of cell towers, because there aren't enough customers to cover the cost of providing comprehensive coverage. Networks that make use of white spaces—unused long-range frequencies in the portion of the spectrum traditionally used by television broadcasters *(see "New Spectrum from Old," p. 73)*—could be a boon for places like these, especially given that a lower population density often means fewer TV stations, leaving more of the spectrum free for data. But even cities will get a boost from white-space technology: the signals can penetrate buildings better than many current wireless alternatives.

Meanwhile, new satellites are delivering services that can provide two-way broadband connections to millions of users. These, too, should benefit rural areas and underserved areas of cities. —*Stephen Cass*





SATELLITE

A new generation of satellites for smart phones are now coming into service. In the future, phones may use a terrestrial network for low-bandwidth interactive tasks and switch to a satellite for high-bandwidth noninteractive tasks, such as streaming video.

4G

LTE and WiMax systems are designed to overcome the interference that results when a signal echoes off buildings. The technology will mean higher data rates and fewer dead zones.

Wi-Fi

This technology works over only a short range but is capable of very high data rates. Many cellular devices are designed to switch to a Wi-Fi network if one is available.

reviews

SOCIAL NETWORKING

Google Misses You

Facebook has corralled 500 million people into an exclusive club that's out of Google's reach. There's no way Google will stand for that.

By PAUL BOUTIN

Last winter, Google made a run at Facebook and fell flat, fast. Google Buzz, the social network it tried to build around its popular Gmail service, failed to live up to its name: it drew only a small fraction of Gmail's more than 100 million users, and it prompted a privacy scare and a lawsuit. But Google didn't give up. Instead, the company is trying again, on a much bigger scale. It has spent hundreds of millions of dollars buying Web companies and luring talent in hopes of stopping, or at least slowing, Facebook's dominance in online social networking. (The project has been dubbed "Google Me," according to people in Silicon Valley who claim inside knowledge.)

Google's social-networking efforts
Facebook

Why would Google—the Web's most profitable public company, an organization that has had no difficulty increasing its commissions from online advertising—have it in for Facebook? It's this simple: Facebook, from the start, has locked Google's Web-crawling robots away from its exclusive club of 500 million members. Just try to search for yourself or anyone else who you know is on Facebook. Google probably won't deliver more than a skimpy profile page whose goal seems to be to get you intrigued enough to sign up for Facebook yourself. Facebook lets members reconfigure their accounts to open their photos and personal information to Google, but it prevents search engines from indexing individual status updates, the site's core content.

Contrast this to Google's relationship with Twitter. Sure, Google Buzz was also an unabashed attempt to divert users from that service—it even borrowed Twitter's language of letting people "follow" each other online. But Google doesn't have to topple Twitter, because Twitter lets Google pay to index its content. The fight between Google and Facebook matters more because these two companies have different visions of the Internet. From Google's point of view, it's as if Mark Zuckerberg has built an off-ramp that whisks Internet users from its superhighway of easily searched information and dead-ends at Facebook's private estate. "Facebook is the Internet as far as many people are now concerned," says Mike Kuniavsky, the author of *Smart Things*, a book about user experience design. "The momentum is enormous." That we-are-the-Internet image is, of course, one that previously belonged to Google.

How could Google get people to quit Facebook? Facebook recently reduced the biggest obstacle, which was that its users were pretty well locked in. People have spent countless hours curating photos, profiles, status updates, and friend lists on the site, and so have their friends. As of October, however, members can click a few buttons to grab everything they've ever uploaded and save it on their computers. Google could take advantage of that by helping people upload their Facebook files into new accounts. Google also could tell people which of their friends had done the same.

But people won't emigrate just because it's easy. "Facebook has gotten more valuable to users over time as more people have joined," says Justin Smith, founder of Inside Network, a market research firm that tracks the site. "Those network effects are difficult to overcome." In fact, it might already be too late. "People abandoning [Facebook] is unlikely," says Bernardo Huberman, director of the Social Computing Lab at Hewlett-Packard. "The only fatal shortcoming would be a very serious breach of privacy that would scare anyone from using it."

So Google needs to offer a reason to leave Facebook. Start with games. More Americans now play FarmVille, the habit-forming game easily accessible on Facebook, than work on real farms. Google has never been a gaming site. But if the company can launch a time-sucking game that Facebook doesn't have, it could chip away at gamers' loyalties. That explains why Google invested between $100 million and $200 million this year in Zynga, the company that created FarmVille and Mafia Wars, another game that's popular on Facebook. Google also spent a reported $70 million for Jam-

PETER ARKLE

bool, maker of the virtual currency Social Gold. Using that currency instead of a credit card would make it easier for people to buy things within Google's games.

Google also could stress a superior user interface. What's the polite way to say that Facebook's is a pain in the ass? Over the past 40 years, computer scientists have developed rules for building interfaces that are considered "intuitive," which means the intended users will be able to figure the thing out without reading a manual, taking a class, or nagging their friends to explain how it works. And yet on Facebook, it can be difficult even to find one's own content, let alone comb through the hard-to-distinguish clutter of wall posts, profile updates, comments, and tags. There's room for a much better way to search social-network content. Perhaps Google can perfect one with the help of technology it got from Like.com, a "visual" search engine it picked up for what appears to be more than $100 million. Or it could tap technology from Ångströ, a social-search company it bought this summer. And taking a cue from its own research, Google could make sure its pages load a lot faster than Facebook's. In tests on its search results pages, Google found that a mere 10th of a second of extra load time chased users away. If Google can make Facebook seem slow, that could make a difference for many people.

Google could also hawk its network as a bastion of personal privacy. As Huberman observes, Facebook's own privacy scares haven't slowed its momentum: people freak out about whether Facebook is following them across the Web or revealing too much about what they do online, and then they use it anyway. But Google's deep-pocketed marketers could launch a campaign that finally tars Facebook as unsafe. The public could be open to that: there's an unease about Facebook that isn't being calmed by this fall's movie *The Social Network*, which portrays Zuckerberg and his early partners as back-stabbing brats who upload other college students' personal info. If Google pitched its social-networking services as a privacy machine, as opposed to a supertool for stalkers, it could reclaim some of the public goodwill that the company lost through its street-view cameras and its on-again, off-again relationship with the Chinese government.

All that said, it's not enough that Google build a better mousetrap. Perfectly good social networks like Friendster, Orkut (a Google product), and MySpace lost users to Facebook simply because Facebook became more popular. If Google is going to lure enough people to matter—hundreds of millions of people—it needs something huge. Something neither you nor I nor Facebook has thought of. Something that will seem too crazy to be true. Think back to Gmail's free gigabyte of e-mail storage, or Google's mind-reading search results that appear while you're still typing. Can the company work up another surprise? Zuckerberg probably believes the answer is yes. This summer he put his crew "on lockdown," with software engineers working nights and weekends. He said the goal was to add features and update the site's design, but any such moves now have a dual purpose: they also shore up Facebook's defenses against a would-be rival. tr

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ELECTRICITY

How *Not* to Make Energy Decisions

Lessons from the battle over Cape Wind.

By EVAN I. SCHWARTZ

America's first offshore wind farm promises to be a picture of ugliness, with 130 turbines, each as tall as a 40-story skyscraper, marring the scenic Massachusetts waters off Cape Cod, Nantucket, and Martha's Vineyard. Or it promises to be a vision of beauty, each white windmill spinning majestically as it produces an alternative to carbon-spewing fossil fuels. But one thing everyone can agree on is that Cape Wind will be big. The turbines, spread out over an area as large as Manhattan, will be visible from the coastline for miles.

There may be no single power project in the United States that has been contested longer and with more vehemence than Cape Wind, which is meant to generate 450 megawatts of power—about as much as a typical coal plant—from the breeze blowing above Nantucket Sound. Ever since it was proposed in 2001, the privately financed developer, Cape Wind Associates, has been locked in a heated war of words with protest groups and tied up in a string of lawsuits. Arguments have erupted over the environmental benefits of the project and the impact of building the massive turbines in an active fishing zone, an area that also serves as a boating playground for some of the world's richest people. The protracted process, fueled by big bucks on both sides, raises a fundamental question that transcends the project itself: Is this any way to make major energy decisions?

Cape Spin: The Fight for the Future of Power in America
Rebirth Productions, 2011

That was the question left hanging in the air after a recent local preview of *Cape Spin*, a new documentary about the project. Above all, the Cape Wind controversy shows that while the problem of climate change is global, it's also true that all energy issues, to paraphrase a famous Massachusetts congressman, are local. And while new power-producing facilities will be most effective if they are sited according to some objective strategy, there's no avoiding the subjective reactions of those who live nearby. In this sense, the showdown over Cape Wind is a microcosm of a much larger debate. "Deciding where to put stuff is never simple," says Lynn Orr, director of the Precourt Institute for Energy at Stanford University. "But this is part of the reason why we've had such a hard time coming up with a national energy policy."

In the film, the camera follows the protests and proclamations of fishermen, sailors, Native Americans, wealthy vacationers, year-round residents, children, business owners, energy executives, lobbyists, and a plethora of politicians, including some from the Kennedy clan, whose family compound in Hyannis Port will have a nearly perfect view

ASSOCIATED PRESS

of the turbines five miles offshore. Many of these people were in attendance at the packed screening of the documentary, which is coming soon to film festivals and is set to air on the Sundance Channel this spring. "Good Lord," its first-time director, Robbie Gemmel, confessed to the crowd. "I didn't know what I was getting into."

Gemmel, who shot 550 hours of footage, says he aimed for an evenhanded approach that also entertains. He begins with the frequently heard notion that the opposition stems from super-rich estate owners who simply don't want their views of the water spoiled. "Remember, they paid good money—or inherited good money—to have these places," says Robert Whitcomb, a newspaper editor who coauthored a 2007 book on the project.

But the demographics of the affected coastal areas are far more diverse than this stereotype suggests. Most of the year-round residents are members of the middle and working classes. To them, the battle is between building a model of a clean-energy future and preserving their way of life. These citizens are portrayed not as victims of the dustup but as active rabble-rousers, planting lawn signs and marching around with banners that shout "Save Our Sound" or "No More Delays" or "Cape Wind Doesn't Float My Boat!"

All along, troops are being massed by the film's two principal characters. Jim Gordon, the president of Cape Wind Associates, is depicted by turns as a tenacious clean-energy champion and a cold-hearted businessman who once tried to construct a diesel power station across from an inner-city school. Before seeing the film, Gordon told me that he hoped it would show how much time and money have already been wasted on the fight. If a small group of local citizens, he says, can hold up a project like Cape Wind, "I want people to see that."

The second main character is Audra Parker, a widowed mother of four who runs the Alliance to Protect Nantucket Sound, the chief opposition group. Her message is crystallized into a sound bite chanted at many protest rallies: "Great idea—but not here!" Parker is able to adapt her main argument to fit the concerns of various audiences: fishermen will be ruined, tourism will suffer, it's about historic preservation, the costs are too high.

If Cape Wind's Gordon gets his way, the turbines will be spinning by 2013. But that victory will have less to do with the economic and environmental merits of offshore wind power than with which side in the local political standoff has best withstood the epic wrangling. Many of the locals have grown cynical: as one citizen says, "The people with the most money are going to win."

These are all valid concerns, and developers who ignore them do so at their peril. "This is a mistake that is made over and over again," says Margot Gerritsen, a colleague of Orr's at Stanford. As an associate professor of energy resources engineering, Gerritsen sometimes attends local meetings and workshops that attempt to hammer out disputes over solar thermal plants in the desert or new transmission lines in rural areas. "People get angry because they feel that they are not listened to," she says. Developers, she adds, need to explain the tangible benefits, such as the prospect of new jobs. She also stresses the need to present hard data from existing energy projects to show the impact on things like real-estate prices and local wildlife.

These local issues are especially tough to sort out because people tend to fear the unknown. "People prefer the evil they know over the evil they don't know," says Gerritsen. Cape Cod, for instance, burns oil to generate electricity. Over the years, tankers delivering oil to the 40-year-old power plant at the Cape Cod Canal have sprung leaks—resulting in spills requiring expensive beach cleanups. What's more, the pollution from its smokestack has contributed to what the American Lung Association calls some of the state's worst air quality. Despite all this, it's still quite common for people to say they'd "rather stick with an old power plant than accept a new one," she says.

Such local debate masks the larger question of whether Cape Wind is a necessary energy alternative. Over the past three years alone, U.S. wind capacity has more than doubled, to more than 35 gigawatts; it now accounts for about 2 percent of America's electricity. But many of the convenient sites suitable for land-based wind farms have already been developed. So even though offshore wind is more expensive (electricity generated by such installations currently costs up to twice as much as electricity from land-based wind farms), developers are now proposing more than 20 plants in U.S. waters—from the Jersey Shore to the Great Lakes to the Gulf Coast of Texas.

No one seems to dispute that many of these spots boast ideal wind resources. In Nantucket Sound, for instance, winds average 20 miles per hour, with little downtime, even in the summer. What's more, the site is protected from large waves by the surrounding land, and it even offers a shallow shoal on which to mount the windmills.

But since the capital costs of building offshore wind farms are high, projected energy prices are steep as well. Under an agreement that must still be ratified by the state utility commission (a decision is expected by the end of the year), Cape Wind has promised to sell half its power to National Grid, a Northeast energy supplier, for 18.7 cents per kilowatt-hour. That's higher than local retail rates for grid energy, which are in the range of 8 to 12 cents per kilowatt-hour. Whether Cape Wind will actually cost or save consumers money in the long run depends in

part on what happens with prices for coal, gas, and oil over the next few years and decades, says Stephen Connors, a research engineer with the MIT Energy Initiative. Power produced by Cape Wind will be used by all National Grid's customers, supplying around 4 percent of a typical customer's energy. At current rates, Connors says, the investment in Cape Wind should cost the average National Grid residential customer anywhere from about $1 per month on the low side to "about two Starbucks lattes per month" on the high side.

In the decade that the battle over Cape Wind has been raging, offshore wind farms have been built in the waters of nine European countries, resulting in a capacity of more than 2.4 gigawatts—enough to power more than a million homes. A 10th country, China, recently completed a 102-megawatt turbine cluster off the coast of Shanghai. By 2020, 30 gigawatts of additional offshore wind capacity is expected to be built off the coasts of China. Yet America's effort to tap offshore wind has lagged.

If Cape Wind's Gordon gets his way, the turbines will be spinning by 2013. But that victory will have less to do with the economic and environmental merits of offshore wind power than with which side in the local political standoff has best withstood the epic wrangling. Many of the locals have grown cynical: as one citizen in the film says, "The people with the most money are going to win."

In fact, it doesn't have to end that way. The turbines, if they're built, will be in public waters leased by Gordon and his associates. That means the public has a right to decide whether the project makes sense as part of a national effort to increase renewable power. But to make decisions wisely, we need a coherent national energy policy and international agreements that make sense of local energy development. In their absence, each new energy project will be caught in the local crosswinds. tr

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TABLETS

Insanely Late

The iPad rivals that are about to flood the market probably have to approach perfection if they are to stand a chance.

By FARHAD MANJOO

It's hard to believe now, but much of the tech world was once convinced that the iPad would flop. The carping began even as Apple CEO Steve Jobs unveiled the device on stage in San Francisco in January. Why did Jobs fail to put a camera on the tablet? How did he expect anyone to surf the Web without Adobe Flash? And what, really, was the purpose of this thing—wasn't it just a big iPod Touch, another iPhone without a phone? Given Apple's determination to control everything people would do on the tablet, the iPad seemed out of step with the history of computing. Here was a machine that was meant only for consuming media, not creating new things. Would anyone go for something so narrowly focused, a computer that was so obviously crimped?

Apple's iPad
Tablet computers coming from other companies

In retrospect, the cognoscenti's case against the iPad—that it was too limited, that it cost a lot more than a netbook yet didn't do nearly as much—was woefully off the mark. Apple sold three million iPads in the first 80 days, and Rhoda Alexander, an analyst at iSuppli, predicts that nearly 13 million will be sold by the end of this year. The numbers suggest the wisdom of the limits Apple imposed on the device. It's true that the iPad doesn't do as much as a normal computer, even a cheap laptop. What many in tech circles didn't get, though, was that people wanted a machine that did less. The iPad's restrictions turned out to be its main selling point: the iPad doesn't do everything a computer can do, but what it does do, it does better or more simply.

It would be wise to keep Apple's tablet strategy in mind as we greet the dozens of iPad rivals that will hit the market over the next year. Some are being pushed by established device makers—Dell, Samsung, Hewlett-Packard, Research in Motion, Lenovo, Asus, and others have announced that they are working on tablets or are rumored to be—while a great many will come from startups and such new players in the consumer electronics business as Cisco Systems. When consumers finally do get a dizzying choice of iPad rivals with expanded features, will the iPad's limitations do it in? Probably not. According to iSuppli, Apple will control about 62 percent of the tablet market in 2012. And that's the *optimistic* scenario for other makers. Rivals looking to make a killing on tablets should face up to a much bleaker possibility—that the iPad will be as dominant as the iPod, which accounts for three-quarters of all portable music players sold in the United States.

To understand why, first consider Apple's unique approach to the tablet. At the Comdex computer expo in 2001, Bill Gates famously predicted that within five years, tablet PCs would become the most popular computers on the market. His vision was based on the Windows operating system, of course; his tablet ran a full-featured version of Windows that was meant to be controlled with a stylus. Not only did this make for an unpleasant interface—Windows was designed for the precision of a mouse, and a stylus felt like a clunky afterthought—but it also misread what people might want in this kind of device. In Gates's view, a tablet would be a full-featured machine. He told the Comdex crowd that he was using one as his "everyday computer." That's where he was wrong—and where Jobs saw an opportunity that the rest of the industry had missed. Apple's genius was in recognizing that not many people are like Bill Gates. We don't want to use

a tablet as our primary computer. Instead, a tablet is a convenience device, just one more machine with which to check e-mail and browse the Web. In this light, the iPad's "limitations" make perfect sense; indeed, it's precisely what Apple omitted that makes the iPad the iPad. Apple realized that a device whose explicit purpose is consumption and convenience—a device marketed for sharing photos, watching movies, flipping through magazines, and reading books—didn't need to be larded with all the extras that techies claimed a successful tablet would need. The lack of Flash is a perfect example. Jobs has complained that Flash would gulp the iPad's battery power and hasn't been optimized for touch-screen devices. Equipping the iPad to run Flash could have added a hassle factor that turned the tablet into something much more like a desktop or laptop computer.

Apple's decision to use iOS, the operating system designed for the iPhone, was another good call. Sure, iOS doesn't offer as many features as Windows or Mac OS X; among many other things, it insists that all programs take up the entire screen, and it offers a limited capacity for multitasking. Yet rather than dooming the iPad, these restrictions immediately defined its place in a household of computers: as a convenience device, it offered less than a desktop but more than a phone. What's more, Apple didn't simply port the iPhone's OS into a larger gadget. It incorporated several new design elements meant specifically for a bigger screen—for instance, new "popover" and "split view" dialog boxes that let sophisticated applications offer choices to users. Apple also invited app developers to create programs specifically for the iPad, nurturing a thriving ecosystem of games and media applications.

The iPad's rivals won't have such an interface or ecosystem anytime soon. Most of Apple's competitors are eyeing one of two main operating systems for their devices: Windows 7 or Android, Google's mobile OS. (HP, which purchased Palm this year, is surely working on a tablet that runs Palm's webOS.) Let's dismiss any possibility that Windows can win significant gains on tablets; though Microsoft has added some touch-based capabilities to the operating system, it is still mainly conceived as an OS for a mouse rather than fingers. That leaves Android. It has become a strong competitor to the iPhone over the last year, with increased market share and ever more interest from software developers. Android is also quite customizable, making it a natural choice for manufacturers looking to enter the tablet market quickly.

But as it's currently conceived, Android faces a key hurdle in this market. Google hasn't offered any specific improvements to the user interface that would make Android more suitable for tablets, as Apple did with the iOS on the iPad. Instead, the task of making the standard Android components work perfectly on a larger screen is being left to manufacturers. As was true in the phone market, some manufacturers will be better at customizing Android than others—leading to a diversity of Android-based tablet designs and a range of user experiences. Having to hunt for the best Android tablet in a forest of subpar devices is likely to annoy some potential customers, while the iPad will be an easy choice—the only tablet sold at the Apple Store.

Another tack for iPad rivals will be to try to fill the most obvious gaps in Apple's device. For instance, many plan to add two cameras (one on the front and one on the back) for easy videoconferencing, and they can tout their tablets' ability to run Flash. More generally, rivals will probably claim to be more "open" than the iPad. An Android tablet might run your choice of Web browser, say, or connect to a Windows computer and play a wide variety of video files from its hard drive—things iPad users couldn't dream of doing. There is also the issue of price. Apple's profit margins tend to be high, and rivals will have room to undercut the $499 it charges for the entry-level iPad. They will team with wireless carriers to offer subsidized versions of their tablets: you'd get the device for $200 or $300 if you signed up for a data plan.

But the iPad's very success suggests the precariousness of this more-for-less strategy. The millions of people who've snapped up the iPad clearly haven't been bothered by its omissions. Are there really that many more customers who are holding out for tablets that include all the bells and whistles Apple's rivals plan to add? Even if we assume, generously, that there is a market for tablets with extra features, it remains unclear how rivals will build such devices without sacrificing the iPad's greatest feature—killer usability.

Apple's rivals don't have much time, and if they want to undercut the iPad on price, they might not have much money to devote to a tablet challenge either.

Creating a tablet that does more than the iPad but is still a pleasure to use will require careful thought, not to mention a lot of time and money. Given the iPad's momentum, Apple's rivals don't have much time—and if competitors plan to undercut the iPad on price, they might not have much money to devote to the project either.

In other words, Apple has boxed its rivals into a corner—just as it did in the market for music players, with its easy-to-use combination of hardware and software. Lots of MP3 players and smart phones can do more than the iPod and the iPhone, and there will soon be lots of other tablets that can do more than the iPad. But in the modern gadget market—a market that Apple has created—selling devices that do "more" isn't good enough. It's doing things better that counts. And it's here that the iPad may have won the race before it even got started. tr

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How to Make an ATM Spew Out Money

By ERICA NAONE

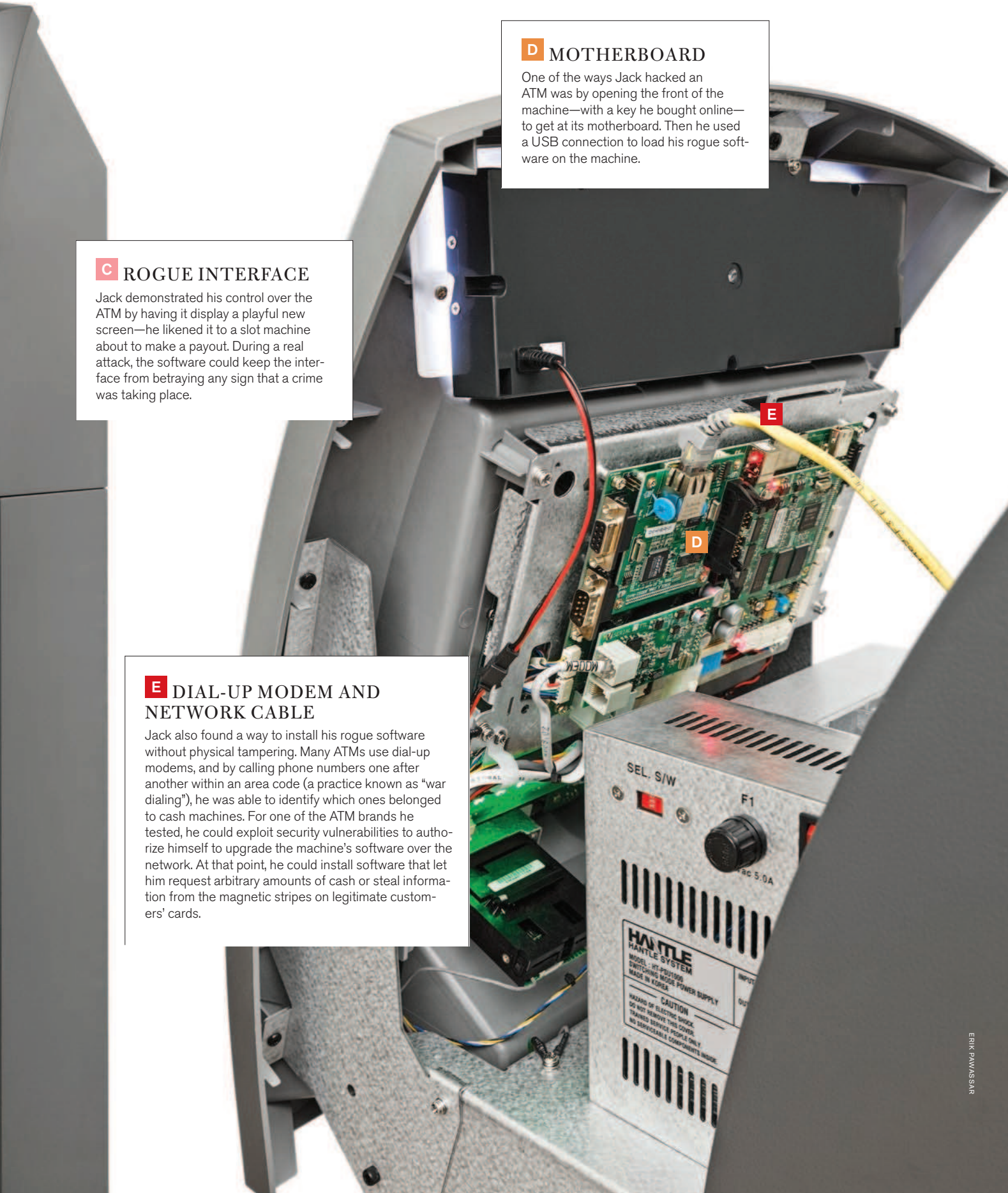
AN ATM STORES cash in a locked vault, and it's usually protected by cameras or other security devices. But that doesn't necessarily mean the dough is safe: like any computerized system, an ATM can be hacked. Barnaby Jack, director of security testing at the computer security company IOActive, recently demonstrated attacks on two brands of freestanding ATMs—the kind found in convenience stores rather than banks. Jack showed he could control when and how they dispensed money. He also found he could steal information from cards that legitimate customers inserted into a hacked machine. He demonstrated two types of attacks—one that required physical access to the machine and one that could be carried out remotely.

A CASH DISPENSER

The ATM's cash dispenser is controlled by electronics that interpret commands from the reader that processes a bank card's magnetic stripe and from the buttons alongside the display. Jack interfered with the program that controls the dispenser and installed his own software.

B VAULT

To break into an ATM without hacking, an attacker would have to open the front of the machine and crack the combination to the safe that holds the money. Jack attacked the ATM's software to make this unnecessary.



D MOTHERBOARD

One of the ways Jack hacked an ATM was by opening the front of the machine—with a key he bought online—to get at its motherboard. Then he used a USB connection to load his rogue software on the machine.

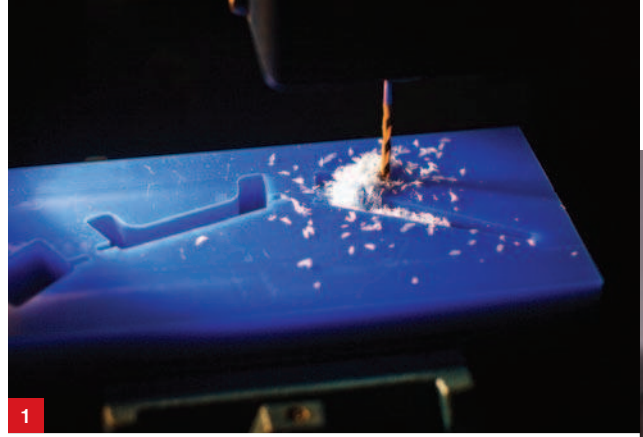
C ROGUE INTERFACE

Jack demonstrated his control over the ATM by having it display a playful new screen—he likened it to a slot machine about to make a payout. During a real attack, the software could keep the interface from betraying any sign that a crime was taking place.

E DIAL-UP MODEM AND NETWORK CABLE

Jack also found a way to install his rogue software without physical tampering. Many ATMs use dial-up modems, and by calling phone numbers one after another within an area code (a practice known as "war dialing"), he was able to identify which ones belonged to cash machines. For one of the ATM brands he tested, he could exploit security vulnerabilities to authorize himself to upgrade the machine's software over the network. At that point, he could install software that let him request arbitrary amounts of cash or steal information from the magnetic stripes on legitimate customers' cards.

ERIK PAWASSAR



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A Gentler Robotic Touch

Simple and versatile robotic hands can grip a football or pick up your keys.

By KRISTINA GRIFANTINI

Inside a new lab at Yale University, a researcher flips a switch, and a robotic hand contracts its four blue-and-white plastic fingers to clutch a football. The researcher takes hold of the base that the hand is attached to and gives it a shake to demonstrate how firm the grip is; then he flips the switch again, and the hand lets go. He moves on to a series of objects scattered on a lab bench, demonstrating how the gripper can in quick succession pick up a telephone receiver, a power drill, and a block of wax.

Engineering robots to grip such random objects has been remarkably difficult. Robotic hands are typically designed with dozens of joints controlled by several independent motors. Coördinating the motors involves complex algorithms that consume lots of computing power, and often robots can pick up only objects they have been programmed to recognize.

But the new hand, designed by Aaron Dollar, an assistant professor of mechanical engineering at Yale, is a study in simplicity. A single motor controls the whole hand by reeling in thin black cables that run through the fingers like tendons. As the motor pulls the cables, the fingers curl around an object much as human fingers would. Unlike conventional robotic hands, which are rigid and made of metal, the plastic fingers have rubbery joints that make them flexible, so they can easily conform to just about any object without damaging it. The controls required for this setup are no more complicated than an on-off switch. "If you design the hardware properly, the software problems become simpler," Dollar says. Indeed, he says, "all you have to do is get close to an object and pull a cable."

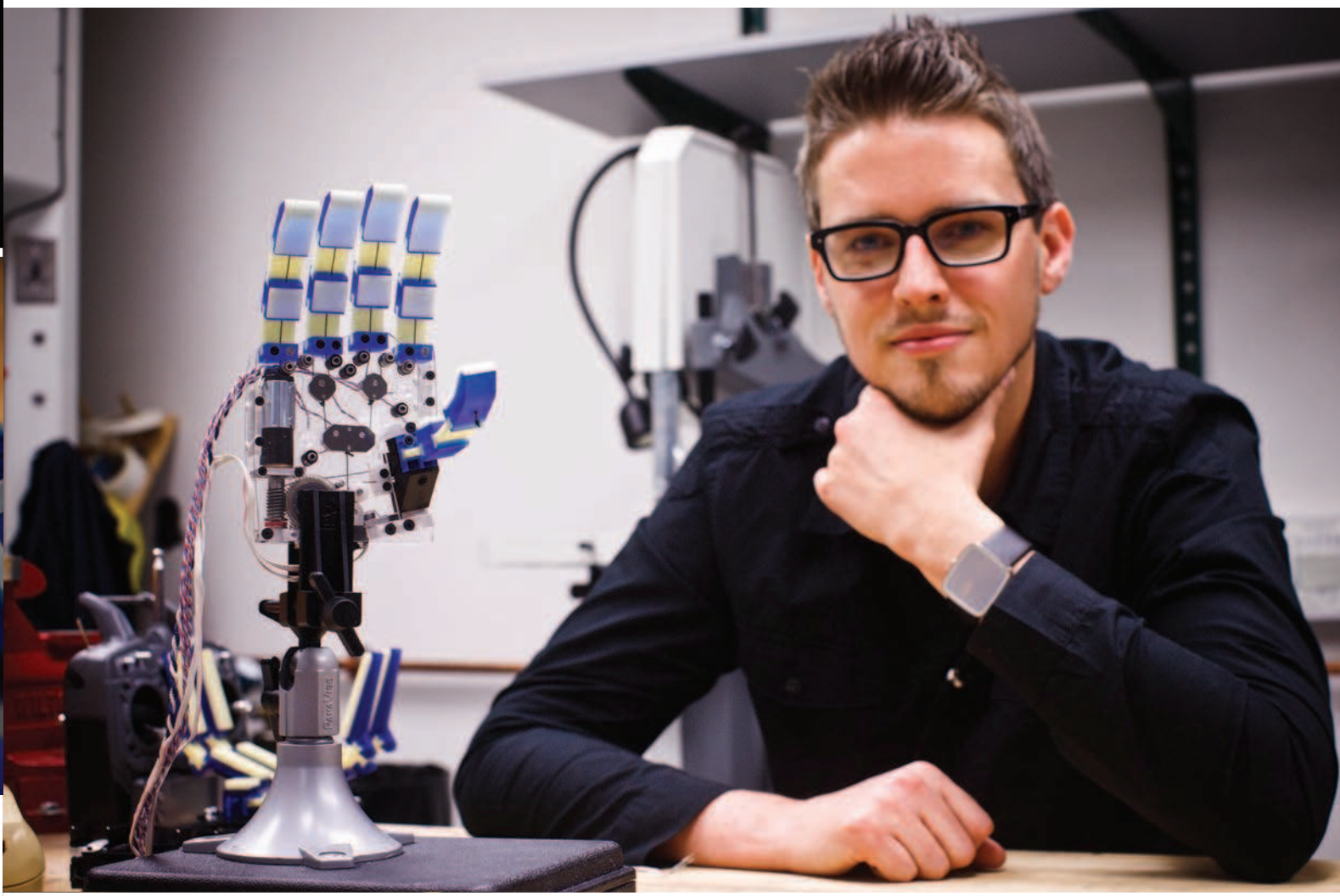
Dollar's lab has made a range of designs, including the four-fingered model and a more humanlike five-fingered hand with a thumb that can be positioned for different grips. By simplifying robotic hands, Dollar hopes to make robots less expensive and more adaptable. That could help lead to practical robotic assistants that are safe enough and deft enough to operate outside the highly regulated environment of a factory floor. It could also give rise to cheap and versatile prosthetics.

MAKING FINGERS

Each finger in the hands is made of three materials: a hard plastic that plays the role of the bones in a human finger, a rubbery plastic that acts as the joints, and a spongy plastic for the finger pads. Ordinarily, making plastic devices involves forming the individual parts in separate molds and then gluing, screwing, or snapping them together. In Dollar's process, each finger emerges fully assembled from a single block of wax, with all the pieces bonded firmly together. That makes the fingers very durable, he says.

Graduate student Joseph Belter starts the process by taking a computer design for

PORTER GIFFORD

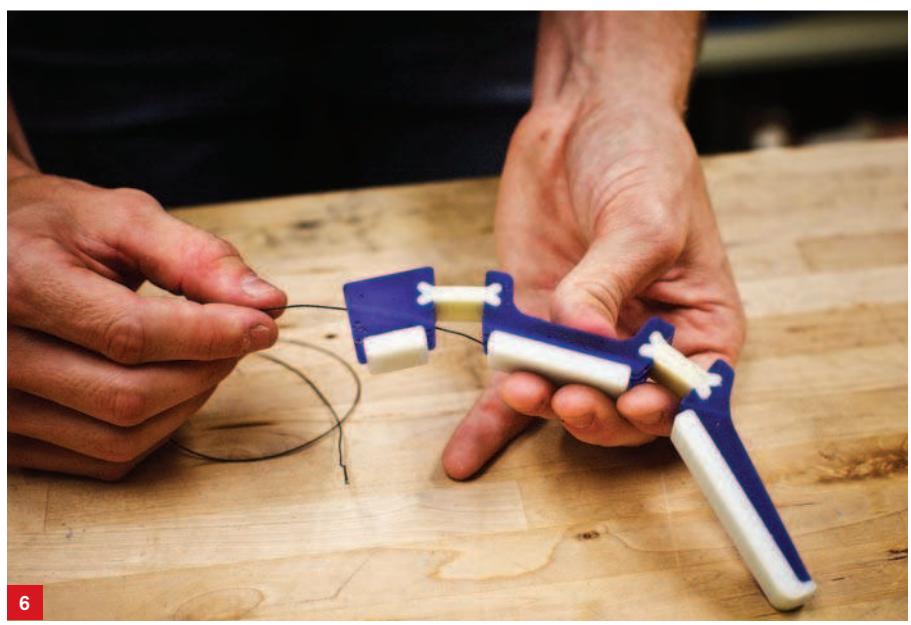


Above: Yale University professor Aaron Dollar poses with a prototype robotic hand that was created in his lab.
1. To begin the process of making plastic robotic fingers, researchers place a block of high-grade wax in an automated mill. Guided by a computer model of a finger, the mill moves the block in three dimensions to carve out molds.
2. After the first mold has been carved, a metal rod is placed inside it (left block). A clay dam is built around the mold, and a dark-blue liquid polymer is poured into it (center block). After the plastic hardens into a solid, the wax block goes back in the milling machine, which carves new molds. These are faintly visible in the block at the far right.
3. A clear plastic degasifying chamber is used to remove bubbles from the liquid polymer before it's poured into the mold. (Bubbles can weaken the plastic.) A pump (left) pulls air from the chamber to create a partial vacuum, which draws the bubbles out.

a finger and entering its three-dimensional coördinates into a computerized mill. He secures a block of blue wax to a movable platform under the mill's drill bit. Motors move the platform under the high-speed mill, which precisely carves out the three-dimensional shapes. These will serve as forms for the hard plastic.

Once the mill is finished carving, the researchers place sensors or other components in the mold in preparation for filling it with liquid plastic; when the plastic hardens, the components will be embedded in the finger. For example, the fingers can be equipped with touch sensors to signal a computer that an object has been successfully grasped. This time, Belter adds only a thin metal rod. When he's finished casting the plastic, he'll remove the rod, leaving behind a raceway for the cable that controls the finger.

Belter mixes liquid resin and hardener under a laboratory hood to create the first plastic, a blue polyurethane material.



4. After constructing new clay dams, a graduate student pours a second liquid polymer into the dog-bone-shaped molds that will shape the finger joints. Next, he will pour a third polymer into the three remaining molds to form soft pads along the length of the finger.
5. After letting the materials used for the joints and finger pads cure for 24 hours, he uses a band saw to cut a few dozen slits close to the finished finger. He chisels away the wax mold with a screwdriver and snaps it off.
6. Finally, he removes the metal rod from the finger and threads in a cable. Pulling on the cable causes the finger to curl up.

He pours it into the mold, where it flows around the metal rod. After the plastic cures and hardens overnight, he puts the block back into the mill to carve the molds for the remaining parts of the finger: the joints and the finger pads.

Belter mixes two polymers for these molds, this time varying the resin and hardener to make a rubbery plastic and a softer one. The latter will produce a spongy—almost sticky—finger pad that gives the robot fingers a good grip.

Once these polymers have cured, Belter trims off any plastic that overflowed the molds. He then cuts slits into the wax and pries it away from the plastic that makes up the finger. He slides out the metal rod he embedded earlier and threads a thin black cable through the tunnels left behind. Later, he'll attach several fingers to a base rigged with pulleys that guide cables from the fingers to the motor that will control the hand.

The process is faster and cheaper than fabrication methods typically used for research robots, Dollar says. That means researchers in his lab are able to quickly test many versions of the robotic hand. One of the finished prototypes, a five-fingered hand, can perform four types of grasping motions, all under the control of one motor: it can turn a key or a knob, grab a dumbbell, gently pick up small objects with the tip of the thumb and forefinger, or combine these grips for oddly shaped objects. That versatility could make the hand useful for prosthetics.

The robotics industry is showing interest in Dollar's innovations: Barrett Technology has licensed the technology and announced plans to make a commercial version of the hand available in 2011. This could be the first step toward a new generation of robots that are simple and adaptable enough to operate not just in factories but in the chaotic real world. tr

www Watch a demonstration of how the robot hand is made: **technologyreview.com/demo**

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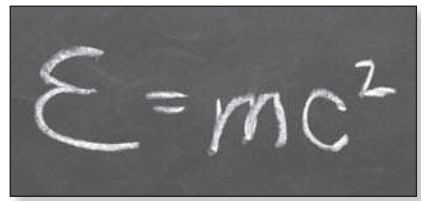

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from the labs

MATERIALS

Capturing Lost Energy

Device harvests power from heat as well as light in solar radiation

SOURCE: "PHOTON-ENHANCED THERMIONIC EMISSION FOR SOLAR CONCENTRATOR SYSTEMS"
Jared W. Schwede et al.
Nature Materials 9: 762–767

RESULTS: A device built by researchers at Stanford University converts both the light and the heat in the sun's radiation into an electrical current.

WHY IT MATTERS: Conventional solar cells can use only a narrow band of the sun's energy; the rest of the spectrum is lost as heat. The most common type of silicon solar cells convert 15 percent of the energy in sunlight into electricity. But Stanford researchers realized that the light in solar radiation could also enhance the performance of a device called a thermionic energy converter, which usually uses only heat. They say that such devices could in theory convert solar energy with 50 percent efficiency.

METHODS: A thermionic energy converter consists of two electrodes separated by a small space. When one electrode is heated, electrons jump across the gap to the second electrode, generating a current. The Stanford researchers found that when they replaced the metal typically used to make the top electrode with a semiconducting material like the ones used in solar cells, photons hitting that electrode also drove current in the device. The Stanford prototype converts about 25 percent of the light and heat energy in radiation into electricity at 200 °C. Conventional thermionic energy converters require temperatures around 1,500 °C, which is impractical for many applications, and conventional solar cells don't function well above around 100 °C.

NEXT STEPS: The researchers are working to make the device more efficient by testing different semiconducting materials for use as the top electrode. They're also redesigning the system to work in conjunction with a solar concentrator that would raise temperatures to 400 to 600 °C. That would produce enough excess heat to harness with a steam engine.

Cell Probes

Nanowire electronics take sensitive measurements inside cells

SOURCE: "THREE-DIMENSIONAL, FLEXIBLE NANOSCALE FIELD-EFFECT TRANSISTORS AS LOCALIZED BIOPROBES"
Bozhi Tian et al.
Science 329: 830–834

RESULTS: Researchers at Harvard have made biocompatible nanoscale probes that use transistors to take precise electrical and chemical readings inside cells. The tips of the probes are about the size of a virus.

WHY IT MATTERS: To create complex bioelectronics such as neural prosthetics designed for fine control of artificial limbs, researchers need to create better interfaces with single cells. Existing electrodes can take intracellular measurements. But to be accurate, they must be large in comparison to the cell and can damage it.

CELL SIGNALS A nanowire probe (thin inverted V) can record signals from cells without harming them.

This work also represents the first time digital devices, in the form of transistors at the tips of the probes, have been integrated with cells.

METHODS: Using a process that they developed, the researchers grow millions of V-shaped silicon nanowires at a time. The tip of each V acts as a very small transistor that can be inserted into a cell to send and receive electrical signals. The probe is more sensitive than a passive electrode, and it can enter cells without damaging them both because it's so small and because it's coated with a double layer of fatty molecules, just like a cell membrane. When placed near the membrane, the cell will actually pull the electrode inside. The electrical and chemical activity inside the cell changes the behavior of the transistor to produce a reading.

NEXT STEPS: The researchers want to incorporate circuits made from the nanoprobes into medical devices, including scaffolds for making artificial tissues. These circuits could "innervate" artificial tissue, mimicking the role of nerves to measure and respond to electrical signals propagating through the nervous system. The researchers also aim to take advantage of the electrodes' ability to send electrical signals in addition to recording them. Applications could include neural interfaces with two-way communication between muscles and the nervous system.

AAAS/SCIENCE (PROBE); LIN ZHONG (ANTENNA)

INFORMATION TECHNOLOGY

Multi-Antenna Cell Phones

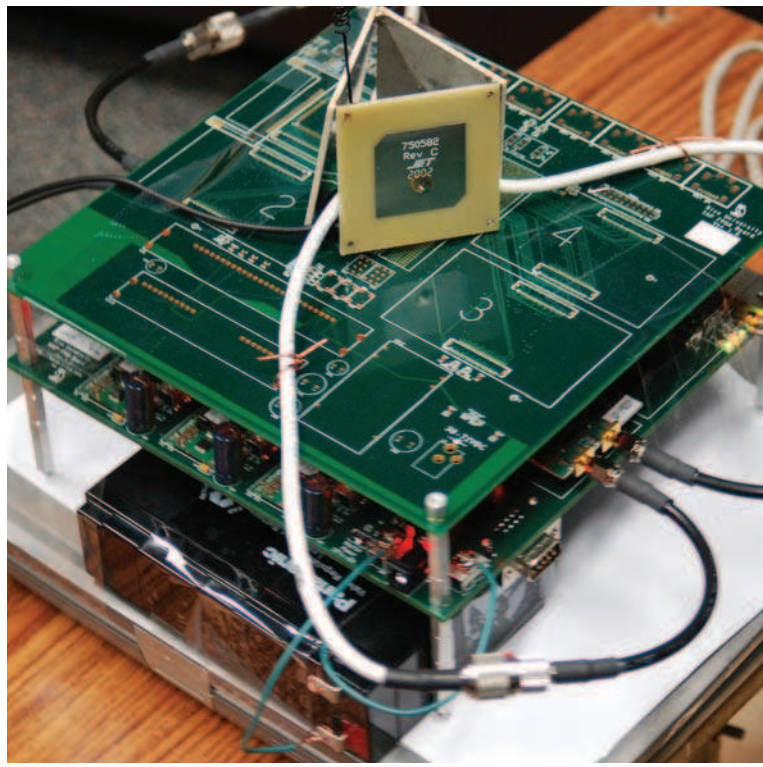
Building wireless gadgets with multiple antennas could extend battery life

SOURCE: "DIRECTIONAL ANTENNA DIVERSITY FOR MOBILE DEVICES: CHARACTERIZATIONS AND SOLUTIONS"
Ardalan Amiri Sani et al.
ACM International Conference on Mobile Computing and Networking (MobiCom), September 20–24, 2010, Chicago

RESULTS: Multiple directional antennas that transmit signals in specific directions conserve power in a wireless device as it connects to its nearest base station. The transmitter selects a certain antenna so that energy is used only to send the signal in the optimal direction. Rapidly rotating the device, forcing it to switch between its antennas, did not interrupt a movie being streamed over the wireless link.

WHY IT MATTERS: Today, gadgets like cell phones beam a signal in all directions, but only a small part of it reaches the receiver. Sending out all that unused energy needlessly runs down their batteries. Directing the signal toward the base station would conserve battery life and reduce interference for other users.

METHODS: Researchers at Rice University in Houston connected a wireless transmitter to three patch antennas, which resemble Band-Aids,



SAVING ENERGY Three antennas (yellow squares), arranged in a triangle, broadcast signals in specific directions.

and mounted the prototype gadget on a spinning platform to see if it could cope with the changes in orientation that affect portable devices. They compared its power consumption with that of a single-antenna device that beams a signal in all directions. They also tested the system's ability to rapidly switch antennas if the one being used was rotated away from the base station.

NEXT STEPS: The researchers are hacking a commercial smart phone to validate the approach on a real phone. They also plan to test whether a phone with one directional antenna on its rear and one on its face would have better signal quality and battery life.

Maintaining Privacy

How to keep information hidden when analyzing network traffic

SOURCE: "DIFFERENTIALLY-PRIVATE NETWORK TRACE ANALYSIS"
Frank McSherry and Ratul Mahajan
ACM SIGCOMM Conference, August 30–September 3, 2010, New Delhi, India

RESULTS: Researchers at Microsoft created a tool kit that makes it possible to analyze real data sets gathered from traffic over a network

MEASURING SUGAR This small implantable device is durable enough to accurately measure glucose in tissue for well over a year.

without compromising the privacy of the information itself. They found that in most cases the analysis was accurate enough to yield useful results.

WHY IT MATTERS: Scientists who want to improve computer networks need access to real-world data so that they can study things like the behavior of malicious software. However, they do not want to accidentally gain access to passwords, private e-mails, and other sensitive information that is sent over the networks they're studying.

METHODS: Researchers developed tools that add noise to small packets of data to mask records that can easily leak private information. The researchers had to be sure the tools introduced just enough noise to preserve privacy while keeping results accurate and calculations simple.

NEXT STEPS: Even with these techniques, a small amount of private information can still leak. The researchers say more work needs to be done to predict and minimize the leaks that will result from repeated analysis of a data set.

BIOMEDICINE

Long-Term Glucose Monitoring

Implanted devices measure blood sugar continuously for many months

SOURCE: "FUNCTION OF AN IMPLANTED TISSUE GLUCOSE SENSOR FOR MORE THAN 1 YEAR IN ANIMALS"
David A. Gough et al.
Science Translational Medicine 2(42): 42ra53

RESULTS: A small device implanted under the skin accurately measured glucose levels in pigs for almost two years.

WHY IT MATTERS: Continuously measuring glucose levels can help diabetics control blood sugar to improve their long-term health. Existing devices for continuous monitoring, which are stuck into the skin rather than fully implanted, have a sensor that must be replaced every few days.

METHODS: Like existing continuous-monitoring devices and traditional fingerstick tests, the new implanted monitor uses an enzyme called glucose oxidase to measure glucose levels. When those levels are high, the enzyme facilitates a reaction that consumes oxygen, a change detected by a neighboring oxygen sensor.

NEXT STEPS: Scientists plan to file for approval from the U.S. Food and Drug Administration to begin human tests. Eventually, they aim to couple this kind of device with one that would automatically deliver insulin in response to changing blood-sugar levels.

Assessing Brain Injury

A portable EEG device shows that neural effects of concussion outlast obvious symptoms

SOURCE: "ACUTE EFFECTS AND RECOVERY AFTER SPORT-RELATED CONCUSSION: A NEUROCOGNITIVE AND QUANTITATIVE BRAIN ELECTRICAL ACTIVITY STUDY"
Michael McCrea et al.
Journal of Head Trauma Rehabilitation 25(4): 283–292

RESULTS: By monitoring football players after blows to the head, scientists found that abnormal electrical activity in the brain persists even after outwardly visible symptoms of the trauma, such as memory or balance problems, have ceased to be detected. Abnormal activity was still present a week after injury but resolved after 45 days.

WHY IT MATTERS: Concussions are currently diagnosed on the basis of symptoms such as nausea and headache, as well as through cognitive and neurological tests. However, more detailed and objective measures are needed to help determine the extent of the injury and to judge when the brain has fully healed. Many scientists and physicians think a blow to the head while the brain is still recovering from an earlier blow might significantly worsen damage, especially in the long term. In recent years, a number of professional football players with a history of head trauma have been found at autopsy to have serious brain damage.

METHODS: The researchers used a portable EEG device developed by BrainScope to determine baseline brain activity at the start of the season for nearly 400 high-school and college football players. Twenty-eight of those players sustained a concussion during the study period. Their brain activity was measured right after the incident and measured again eight days and then 45 days later.

NEXT STEPS: BrainScope is using the device to study brain injury in military personnel and emergency-room patients. tr

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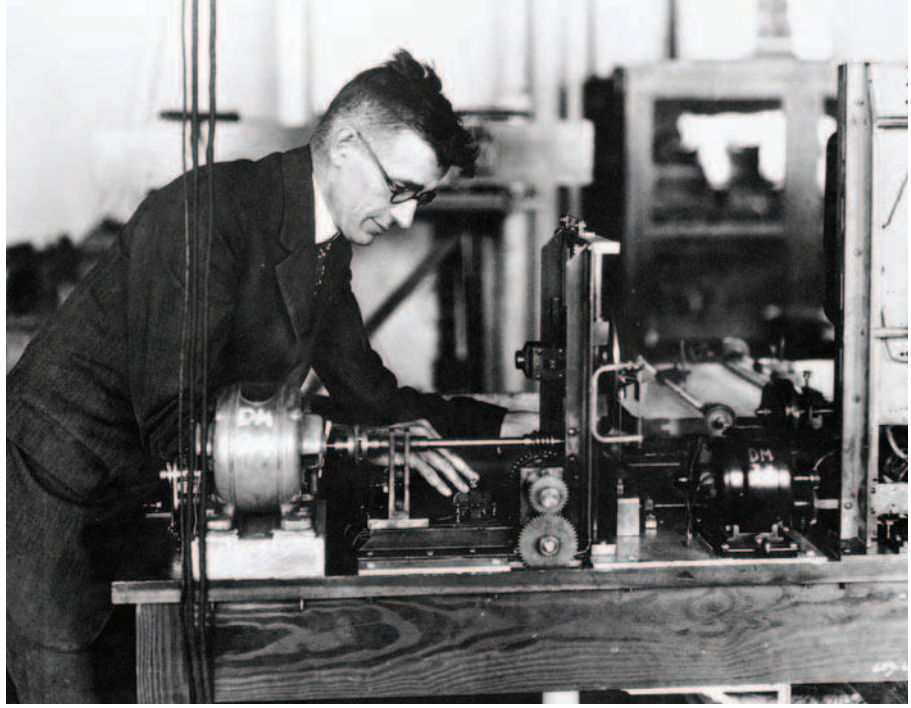
Future Perfect

Vannevar Bush gave Depression-era readers a glimpse of technological advances to come

By MATT MAHONEY



NEXT STOP: IPAD Vannevar Bush, shown here with an analog computer he'd invented, imagined a day when tiny devices contained libraries.

In a 1933 essay for *TR*, Vannevar Bush, then MIT's dean of engineering, wrote a sardonic report in which he pretended to be somebody from the distant future who looked back with distaste on the "preposterous" and "grotesque" state of technology in the 1930s. To illustrate his points, he followed a hypothetical professor confronting the various indignities of a typical day.

We read of the trials of the men of that day and wonder that they could have been apparently content with their mode of life, its discomforts, and its annoyances. Instead, we should admire them for having made the best of a hard situation, and treasure the rugged qualities which they exemplified ... Consider, for example, a professor in some northern urban university, and let us attempt to appreciate the sort of life he led, with a sympathetic attempt to evaluate the extent to which his efforts were circumscribed by the hardships and discomforts of his daily existence.

In a sense, Bush's article was just a way to poke fun at himself and his contemporaries. The telephone, he lamented, distorted the professor's speech while ensnaring him in a tangle of wires; the incessant clatter of the typewriter in his office made thought impossible; he actually had to be present in the classroom to give his lectures rather than broadcast "a much more finished presentation by vocal cinema." But the essay also demonstrated the visionary intelligence that Bush would put to good use during World War II as director of the Office of Scientific Research and Development (the office's support of radar research was critical to the war effort). His criticism of life in the 1930s sprang from his conviction that future technology would improve things. Take the university library, the sheer scale of which made finding relevant information time-consuming and difficult:

The library, to which our professor probably turned, was enormous. Long banks of shelves contained tons of books, and yet it was supposed to be a working library and not a museum. He had to paw over cards, thumb pages, and delve by the hour. It was time-wasting and exasperating indeed. Many well remember the amazing incredulity which greeted the first presentation of the unabridged dictionary on a square foot of film. The idea that one might have the contents of a thousand volumes located in a couple of cubic feet in a desk, so that by depressing a few keys one could have a given page instantly projected before him, was regarded as the wildest source of fancy.

Historians of science see this sentence as Bush's first description of a device he eventually dubbed the "Memex," which he introduced more fully in a 1945 article for the *Atlantic Monthly*. From a technological perspective, the predigital device that he conceived was nothing more than a souped-up microfilm reader. But the idea of a personal information indexing and retrieval device directly inspired the inventors of hypertext, the basic organizing principle of the Web. Bush's idea also foreshadowed the development of intuitive, easy-to-use tablet computers like the iPad. Bush saw the development of such devices as inevitable, and he imparted his vision to his students, including Claude Shannon. Four years later, Shannon would prove that electrical circuits could be used to perform logic operations, thus initiating the digital revolution that made it all possible.

The technologies we now take for granted would have solved many of the problems that Bush's hapless professor faced. But his accounting of the shortcomings of his own era might just as well be applied to our own.

It may be asked why, with all this opportunity, we had to wait so long for the obvious ... Perhaps it was ascribable in a measure to the prevailing social code which then forced all men to dress alike and, to some extent, to think alike. Or, it may have been that the pressure of advertising propaganda had induced a mass psychology which led people to believe they had arrived at some sort of mechanical Utopia with which they were duty bound to be content. tr

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